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Relationship between Spatial Intelligence and Performance of Chemistry Majors at Philippine Normal University

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Relationship between Spatial Intelligence and Performance of Chemistry Majors at Philippine Normal University

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APPROVAL SHEET

In partial fulfillment of the requirements for the degree Master of Arts in Science Education with Specialization in Chemistry, this thesis entitled "**Relationship between Spatial Intelligence and Performance of Chemistry Majors at Philippine Normal University**" which was prepared and submitted by **Mr. Larry F. Tengco**, is hereby recommended for approval and acceptance.

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Larry F. Tengco
Researcher

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ABSTRACT

Name	:	**LARRY F. TENGCO**
Title of Thesis	:	**Relationship between Spatial Intelligence and Performance of Chemistry Majors at Philippine Normal University**
Key Concepts	:	Spatial Intelligence, Chemistry Performance
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The study aimed to determine the level and the relationship of spatial intelligence which is composed of four domains namely: abstract reasoning, mechanical reasoning, manipulation in two dimensions, and manipulation in three dimensions of the PNU Chemistry majors and their achievement in Chemistry. The study was conducted to present descriptive data on the respondents' level of spatial intelligence and their achievement in Chemistry.

The study used the causal-comparative descriptive research method. A total of 43 Chemistry majors from second year to fourth year level at the Philippine Normal University were chosen to be the respondents. Instruments used were: achievement test to measure performance involving concepts in chemistry, spatial intelligence aptitude test to measure the level of spatial intelligence, and organic

chemistry spatial performance test to measure the achievement of the students in organic chemistry topics which require spatial manipulations.

The result of the study showed that the respondents had an average level of spatial intelligence. The majority of the respondents had a good level of performance in the achievement test. The level of spatial intelligence of the respondents had a low correlation but showed a significant relationship with their chemistry achievement. On the other hand, the organic chemistry spatial performance test performance had a moderate correlation and showed a highly significant relationship with chemistry achievement which made the organic chemistry spatial performance test performance the best predictor of their chemistry achievement.

CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Introduction

Intelligence is a concept associated with human behaviors that people value in different social and cultural contexts. According to Diezmann et al. (2000), education has targeted the development of skills and acknowledged those areas as vital in formal education. Over time, the idea of intelligence has been modified to suit the needs of society. In prehistoric times, intelligent human beings were referred to people who had the skills to forage for food and to predict natural events through the movement of stars. Extremely competent at doing the tasks, elders fostered these skills during their youth. In today's society, where globalization and technology are a dynamic means, intelligence is viewed differently and the emerging definitions of intelligence are vital issues to contemporary educators.

Intelligence has been valued by those who are highly literate. However, Diezmann et al. (2000) also propose that a careful analysis of highly creative people in the area of mathematics and science, and recognition of the impact of technology in an information age suggests that other behaviors broadly identified as spatial intelligence are significant areas of human capability.

Spatial intelligence represents a collection of behaviors that are deemed vital; however, in modern education, seemingly, they received a little or less attention.

Societal changes that are associated with technology underscore the importance of spatial intelligence. Recently, through the work of Gardner (2011), spatial intelligence has been recognized and given much attention. The interpretations of Gardner's work, however, were focused only on the importance of spatial intelligence in creative domains and not on the crucial role that spatial intelligence plays in the mathematical and scientific domains.

Admittedly, Chemistry is known to many as a difficult subject. The perceived difficulty may be caused by lack of concrete or abstract visualization and/or appropriate teaching methodologies. According to Gabel (1999) "The primary barrier to understanding chemistry is that chemistry instruction occurs predominantly on the most abstract level, the symbolic level. To address issues on visualization, educators and learners alike, ought to understand available information on the issue especially those that are brought by research. For instance, the ability to manipulate objects without physical being is an essential skill in understanding the concept of chemistry. This ability enables spatial students to get more interested and motivated to learn science concepts which eventually results in better overall performance in Chemistry.

This study determined the levels of spatial intelligence in the different domains among the Chemistry majors in Philippine Normal University. Likewise, the study found out whether the respondents' level of spatial intelligence affected their general performance in Chemistry.

Conceptual Framework

This study was anchored on a number of theories on or related to the relationship between spatial intelligence and academic performance of students in chemistry.

Multiple Intelligence Theory

As indicated by Gardner (1983), intelligence is "the capacity to take care of issues, or make items, that are esteemed inside one or more social settings." To further illustrate this definition, Gardner (1983) recognizes seven intelligences. These initial seven intelligences incorporated all those previously stated except the Naturalistic which was later added to Gardner's schedule in 1999.

There are two different intelligences that Gardner presently concentrates on: Existential and Moral. However at this point, they are not viewed as a major aspect of the center eight intelligences. No intelligence is said to be viewed as more excellent or more critical than whatever available, and in spite of the fact that every person has each of the eight intelligences, the level of every type differs from individual to individual (Smith, 2002, 2008).

The eight intelligences in Gardner's Theory of Multiple Intelligences are characterized as the following:

Linguistic intelligence depicts an individual who is word shrewd; one who is fit for utilizing and comprehension words successfully.

Logical-Mathematical intelligence is the capability to sense examples, conclude rationale, and perform numerical estimations.

Musical intelligence goes past the basic capability to listen to or comprehend music and understanding rhythms and tones and the capacity to recognize a relationship between sound and feelings.

Bodily-Kinesthetic intelligence addresses the individuals who have mastered their body developments and movements, can control objects effectively, and can express ideas through movement, for example, dancing.

Spatial intelligence talks about mental abilities of imagining pictures and space. It is the understanding of conceptual ideas and spatial mindfulness.

Interpersonal intelligence describes an individual who can undoubtedly distinguish other's feelings and conduct and has a tendency to work well with others.

Intrapersonal intelligence characterizes the individuals who can sense their own particular sentiments and comprehend their own particular qualities and shortcomings.

Naturalistic intelligence is the capacity to comprehend and gain from one's nature (Chapman, 2003).

Spatial Intelligence

Spatial intelligence can be inferred from the ability to invoke and use specific representations and reasoning. In addition to imagery, as identified by Einstein (1949), spatial representations include diagrams, drawings, maps, and models. Reasoning with spatial representations differs substantively from the sequential reasoning used with linguistic representations, such as text and involves cognitive interaction with spatial information to solve problems (Rogers, 1995). Spatial intelligence includes an ability to perceive and represent the visual-spatial world accurately and to form and manipulate mental images (Gardner, 1983, 1993a, 1993b, 1997 and 2011). Although traditional IQ tests may be a valid measurement of linguistic or logico-mathematical intelligence, they are not a valid measure of spatial intelligence. However, there are numerous tests of spatial intelligence that quantify discrete factors associated with spatial representation and spatial reasoning (Lohman et al., 1987). These factors include spatial perception, spatial visualization, and mental rotation.

Stieff (2004, 2007) investigated expert and novice chemists' performances on a classic visual-spatial task, the mental rotation of three-dimensional figures. He used the classic Shepard and Metzler (1971) figures, which resemble three-dimensional blocks arranged in different positions. The participant's task is to decide whether a given block is a rotated version of a target. In addition, Stieff also included representations of three-dimensional chemical molecules. These were chemistry diagrams that are commonly taught in first- or second-year college chemistry classes.

A great deal of attention is devoted in chemistry to the study and behavior of isomers, which are compounds with identical molecular compositions, but different spatial configurations. A particularly important spatial property of isomers is chirality, or handedness. A molecule is chiral if its mirror image cannot be superimposed on itself through rotation, translation, or scaling. Molecules that are chiral opposites are called enantiomers. Chemistry teachers often use a classic analogy to explain chirality, namely, the spatial relation between a person's right and left hand. Although they share the same set of objects (fingers and thumbs), and the same set of relations among these objects, it is not possible to superimpose the left hand onto the right hand. Chemists and physicists have adopted this embodied metaphor, often referring to left and right hand configurations of molecules.

Individuals who are high in spatial ability but not as exceptional in mathematical or verbal abilities constitute an untapped pool of talent for STEM domains (Wai et al., 2009). Although there are certainly teachers who have high spatial ability, people with education degrees have lower spatial and math abilities compared with engineers, mathematicians, etc. Teachers, just like anyone else, tend to relate to students who have similar strengths as their own. Therefore, it would make sense if teachers do not recognize spatial talents as important as math and verbal talents simply because these teachers have never really found them important in their career or their personal lives (Wai, 2012).

Figure 1 shows the paradigm of the study.

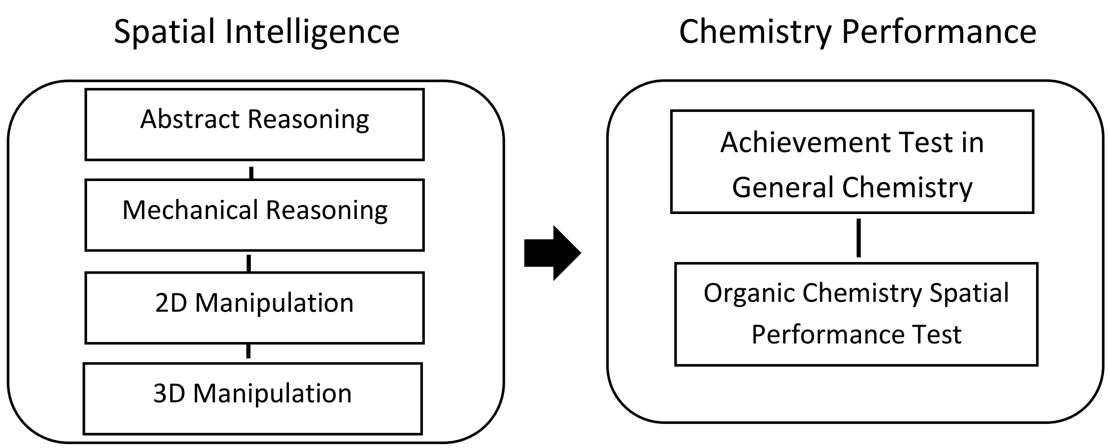

Figure 1. Paradigm of the Study

The study tested the relationship between the level of spatial intelligence and performance of students in chemistry. This test was done by administering a series of tests to measure the level of spatial intelligence, chemistry achievement, and spatial achievement performance of the respondents. Although there are more factors that contribute to the performance of the students like age and gender, spatial intelligence is a major contributor to the performance especially in an abstract subject like Chemistry.

The variables of the study were concentrated on the four domains of spatial intelligence namely Abstract Reasoning, a nonverbal measure of finding logical relationships in sophisticated figure patterns, Mechanical Reasoning, the ability to deduce relationships between gears, pulleys, and springs as well as their knowledge of the effects of basic physical forces, Two-Dimensional Spatial Visualization, the ability of the respondents to visualize two-dimensional figures when they were rotated or flipped in a plane, and Three-Dimensional Spatial Visualization, the ability of the respondents to visualize two-dimensional figures after they had been folded into three-dimensional figures.

The study also focused on the Chemistry achievement of the respondents which includes an Achievement test and the Organic Chemistry Spatial Performance Test. While they both measure the achievement of the respondents, both have distinct characteristics which differentiates one from the other. The Achievement test measures the conceptual understanding of the respondents in General Chemistry while the Organic Chemistry Spatial Performance Test measures the conceptual and the spatial skills of the respondents.

As Wai et Al. (2009) stated, individuals with high spatial abilities tend to go to STEM fields. As such, there must be a relationship between spatial intelligence and achievement in such fields (i.e. Chemistry). It is also worthy to note that spatial intelligence is needed in organic chemistry as the subject involves mental rotation of molecules. Uttal, D & Cohen C. (2012) stressed that spatial skills are essential in molecules which exhibits chirality because of their orientation in space. Due to its highly spatial characteristic, there must be a relationship between spatial intelligence and organic chemistry performance.

Statement of the Problem

The primary focus of the study was to determine the relationship between the levels of spatial intelligence of Chemistry majors at Philippine Normal University and their performance in Chemistry.

Specifically, the study sought to answer the following questions:

1. What is the spatial intelligence profile of the students in the following domains?
    a. Abstract Reasoning (ABS)
    b. Mechanical Reasoning (MECH)
    c. Manipulation in Two Dimensions (2D)
    d. Manipulation in Three Dimensions (3D)
2. What is the chemistry performance of the students be in terms of the following?
    a. Chemistry Achievement Test (ACH) scores
    b. Organic Chemistry Spatial Performance Test (OCSPT) scores
3. Are there significant differences in the chemistry performance of students when they are categorized according to the spatial domains?
4. Is there a significant relationship between the spatial intelligence domains and chemistry performance of the students?
5. Which domain of spatial intelligence the best predicts the chemistry performance of students?

Significance of the Study

The study aimed at finding out the relationship between the level of spatial intelligence of the Chemistry majors at PNU and their level of performance in Chemistry. It hoped to generate information on the relationship of the level of spatial intelligence and chemistry performance of students.

Specifically, the study hopes to benefit the following:

Students. The result of the study will serve as a self-assessment for students to keep track of their progress and skills. It will also serve as a guide in choosing a course to take up. They can base their decision not only on their preferences but also on the level of their cognitive skills to reduce their difficulties in learning.

Teachers. The result of the study will serve as a guide for teachers in choosing an effective method they will use to assess the level of spatial intelligence of their students. This will not only lessen the work done by teachers but also make the lessons more meaningful to students. This will also enable the students to raise their level of spatial intelligence and, ultimately, to be ready to pursue higher education.

School Administrators. The result of the study will help the school administrators in choosing the qualified applicants for a specific course program by scheduling a spatial intelligence test as part of their admission requirements. This will enable them to admit applicants who have the appropriate cognitive level required by the course and reduce the rate of students shifting courses or dropping out. This will also ensure the quality of graduates the school will produce.

Parents. The study will help the parents in guiding their children in choosing the right course to take up. Information generated through this study will help parents help their children improve performance which will eventually help them succeed in school and later on in life.

Curriculum Planners. The finding of the study will help curriculum planners improve the curriculum by designing the topics, objectives and instructions in such a way that they would develop the spatial ability and eventually improve learning of the students.

Future Researchers. The study will encourage future researchers to embark on multiple intelligence studies to further understand how students perform in chemistry and in other subjects.

Scope and Delimitation of the Study

This study was delimited to the determination of the relationship between the students' level of spatial intelligence and their achievement in chemistry. The respondents of the study were taken from the Bachelor of Secondary Education major in Chemistry and Bachelor of Science in Chemistry for Teachers students from second to fourth year level at Philippine Normal University who were enrolled in the second semester of school year 2013-2014. Three instruments were used in this study namely, Spatial Ability Test, a 75-item multiple choice test comprising of Abstract reasoning, Mechanical Reasoning, Manipulation in two dimension, and Manipulation in three dimension, An Achievement Test which is a 50-item multiple choice test consisting of General Chemistry topics and an Organic Chemistry Spatial Performance Test, a five item open ended question test measuring the spatial and conceptual knowledge of the students on certain topics in Organic Chemistry.

Definition of Terms

For better understanding of the study, the following terms were hereby defined.

Abstraction. This refers to the ability to convert concrete objects to abstract concepts.

Achievement. This refers to the same performance of the student in the achievement test.

Composite score. This refers to the weighted sum of all the spatial intelligence domain scores.

Organic Chemistry Spatial Performance Test (OCSPT). This refers to an open-ended test with conceptual and spatial components in selected organic chemistry topics.

Performance. This refers to the result of the achievement test and the organic chemistry spatial achievement test.

Spatial Intelligence. This generally refers to the intelligence which involves visualization, rotation, transformation, and manipulation of objects but in the study, it corporates four domains namely, Abstract Reasoning, Mechanical Reasoning, Manipulation in two Dimensions and Manipulation in three Dimensions.

CHAPTER II

REVIEW OF RELATED LITERATURE AND STUDIES

This chapter presents a brief review of the related literature and studies from books, journals, periodicals, and internet which are related to the problem at hand. They are cited to add insights into the present research.

Intelligence

Intelligence is an idea that thinkers have grappled with since the early times (Sternberg, 1990). Most people see intelligence as a characteristic of cognitive attribute associated with the competence in learning. Intelligence empowers individuals to work on natural signs to construct comprehension and react to their circumstances. It is the force, pace, and ability to overcome obliviousness and be "goal responsive." Formal testing to recognize around individuals on the basis of some intellectual skill is emphasized in both Western and Eastern traditions. For instance, Civil administration examinations predominated in the Chinese realm for 3000 years (DuBois, 1966). Furthermore, testing was endemic in Greek education. In the late 19th century and start of the 20th century, a convention of individual differences was launched by Francis Galton in the United Kingdom and subsequently by James Cattell in the US (Anastasi, 1968). These individuals utilized a variety of tests including sensory discrimination and reaction time as quantifies of intellectual function. Francis Binet, who specifically identified "subnormal" children for the French

Ministry of Public Instruction, accepted tests of judgment, comprehension, and reasoning as quantifies of intelligence with outcomes expressed as mental age. Binet's tests in the US reported performance as a proportion of mental age and sequential age which was characterized as an intelligence quota or IQ. Aptitude tests that quantifiy a reach of aptitudes as "factors" of a general intelligence were produced in the 1930s (Eliot, 1987). Thus, for much of the 20th century coincident with the expansion of formal education, intelligence was closely associated with general performance in formal school-related tasks. This tradition of viewing intelligence as a single entity has been challenged in more recent times.

Hypothesis of Multiple Intelligences

Gardner’s hypothesis of Multiple Intelligences has broadened the view of intelligence (Gardner 1983, 1993a, 1993b, 1997 and 2011). Gardner proposes that there are at least eight different and discrete facets of cognition, which can be regarded as relatively independent human intelligences. These intelligences are described as logical-mathematical, linguistic, musical, spatial, bodily-kinesthetic, interpersonal, intrapersonal, and naturalistic. Gardner’s hypothesis explains the diversity of profiles of intelligences within the normal population and the exaggerated cognitive profiles in the variety of special populations, such as the gifted, prodigies, and idiot savants. The educational implications of Gardner’s hypothesis are extensive and include appreciating and recognizing the characteristics of the various intelligences, and nurturing the diversity of intelligences of children.

In contemporary society, technology has taken over many of the menial tasks that were appreciated in former times. Speed in mathematical computation, word processing, electronic communication, and the convenience of information, all achieved through technology, have transformed society. The skills and attributes now appreciated are different from those that dominated previous eras, which compel as educators to examine what are deemed essential in formal education. In an industrially oriented society, spatial intelligence is of specific importance.

Spatial Intelligence

Spatial intelligence, which also has been signified to as spatial ability, involves the manipulation of information presented in a visual, diagrammatic, or symbolic form in contrast to verbal, language based modality. Spatial intelligence may manifest as a specific aptitude for thinking and communicating spatially. For example, Einstein, the most renowned scientist of the 20th century highlighted his thinking processes in the following reflection:

> “The words or the language, as they are written and spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be voluntarily reproduced or combined. The above-mentioned elements are, in my case, of visual and some of muscular type. Conventional words or other signs have to be sought for laboriously in

> a secondary stage, when the above mentioned associative play is sufficiently established and can be reproduced at will.”

Spatial intelligence can be inferred from the ability to invoke and use specific representations and reasoning. In addition to imagery, as identified by Einstein (1949), spatial representations include diagrams, drawings, maps, and models. Reasoning with spatial representations differs substantively from the sequential reasoning used with linguistic representations, such as text and involves cognitive interaction with spatial information to solve problems (Rogers, 1995). Spatial intelligence includes an ability to perceive and represent the visual-spatial world accurately and to form and manipulate mental images (Gardner, 1983, 1993a, 1993b, 1997 and 2011). Although traditional IQ tests may be a valid measurement of linguistic or logico-mathematical intelligence, they are not a valid measure of spatial intelligence. However, there are numerous tests of spatial intelligence that quantify discrete factors associated with spatial representation and spatial reasoning (Lohman et al., 1987). These factors include spatial perception, spatial visualization, and mental rotation.

Prior to Gardner’s work, spatial intelligence was recognized and measured from factor analysis of performances on aptitude tests. Spatial ability was appreciated in careers relating the need to interpret spatial information. For example, for many years, tests of spatial ability were used extensively to predict aptitude toward careers relating aviation, engineering, or technical drawing. Spatial intelligence is also recognized among nomadic peoples and has been described as an essential attribute among hunter-gatherers.

Spatial Intelligence and Mathematics and Science

In recent times, spatial intelligence has been commonly associated with art, perhaps because Gardner (1993b) cited Picasso as an exemplary spatial creator; however, there are also many examples of outstanding mathematicians and scientists with high spatial ability, in addition to Einstein. Indeed, some like Leonardo daVinci expressed their spatial intelligence in both the artistic and scientific domains. Indeed, spatial intelligence has long been implicated in mathematics and science achievement at school. Many studies have recommended a correlation between high spatial intelligence and achievement in mathematics. A study conducted by Kayhan (2005) showed that there was a statistically significant relationship between the students' mathematics achievement and their spatial ability. it was also seen in that study that the relationship between the students' spatial visualization abilities and mathematics achievement was not as strong as the relation between their spatial orientation abilities and mathematics achievement. Likewise, in science, students with high spatial intelligence have tended to perform better in tasks needing problem solving and mental manipulation of two-dimensional objects or symbolic representations (Carter, Larussa, and Bodner, 1987; Gabel and Bunce, 1994; Pribyl and Bodner, 1987). Spatial visualization skills are also recognized to be of importance in biology and astronomy (Ault, 1994). Interestingly, there seems to be a two-way interaction between spatial ability and participation in physics. A study by Pallrand and Seeber found out that spatial abilities affected students' decisions to study college physics and that these abilities improved in those students who did study physics. Graphic user interfaces in computers capitalize on spatial intelligence to use information technology effectively.

In the early childhood years, the foundation for science and mathematics is built through play. Mitchell and Burton (1984) argue that the use of construction toys "further the improvement of spatial ability" and may afford opportunities for children to value and exploit their spatial skills. The importance of play in facilitating the improvement of high achievement in science cannot be underestimated. The renowned physicist Feynman recognized his early experiences with tinkering as founding a long term connection in play and modelling to which he recognized to his achievement in achieving the Nobel prize (Gleick, 1992). Others have also argued for the importance of play in the foundations of suitable a scientist (Wasserman, 1992).

Employing diagrams holds additional, specific benefits for spatial reasoning and problem solving: Representational properties of diagrams (e.g. concerning spatial indexing of information or representational specificity) lead to favoring certain (perceptual) inferences and structural interpretations over others. This effectively introduces heuristics which help reduce inferential and representational complexities. Re-representation sequences that consist of repeatedly externalizing visuo-spatial knowledge in diagrammatic formats and then reading off information from diagrams are in fact a powerful driving force in many visuo-spatial reasoning and problem solving processes; they have been extensively studied, for example, in architectural design research (Bertel, 2009).

Examination of Spatial Expertise

A complementary approach over the last few years is to examine domains of expertise that demand spatial thinking to analyze the types of tasks that experts in these domains have to accomplish, and the spatial cognitive processes with which they struggle. In addition to examining spatial expertise "in the wild," these cognitive processes were attempted to be brought under experimental control and the standardized quantification of these processes be developed so that they can be studied in a more detail in the laboratory. This approach allows the researchers to identify spatial cognitive processes that appear to be essential to spatial thinking in the real world and that are not always well captured by existing tests of spatial ability. As a result, the researchers have studied a wider variety of spatial thinking tasks than are quantified by the most commonly used spatial ability tests, and they do not consider a correlation with spatial ability quantifies to be a prerequisite for classifying a task or domain as relating to spatial thinking. To date, the researchers have examined aspects of spatial thinking in medicine (surgery, radiology, and learning anatomy) (Stull, Hegarty, & Mayer, 2009), mechanical reasoning (Hegarty, 1992;

2004), and physics problem solving (Kozhevnikov et al., 2007), and a current research project examines spatial thinking in organic chemistry.

These domains have several essential characteristics in common. First, they are concerned with encoding, maintaining, and inferring information about spatial structures and processes. For example, in learning anatomy, medical students need to learn the shapes of three-dimensional objects, the spatial relations between parts of these structures and how they are connected in three-dimensional space, while chemists have to reason about how atoms combine in characteristic substructures, to compose complex molecules. In terms of processes, mechanics have to infer how the parts of an engine should move, on the basis of its structure (e.g., the shape, material composition, and connectivity of its parts) to diagnose why a faulty engine is not working properly. Meteorologists need to infer how pressure systems develop and interact with the surface topography of a region and moisture in the atmosphere to cause heat waves, thunderstorms, and sundowner winds. In the subject of geography, the ability to encode and decode maps. For the purpose of map reading, encoding is the process of putting together a sequence of symbols into a specialized format for efficient transmission or storage. Those symbols typically appear in a map legend such as a star for a capital or a blue line for a river. In other words, to read maps effectively, one must be able to both break apart and put together the components of a map to transfer and internalize its meaning (Cohen, 2011).

These domains rely on some of the same cognitive processes as a psychometric measure of spatial visualization, which quantifies ability to mentally rotate objects, imagine objects from different perspectives, imagine folding and unfolding of pieces of paper, and mentally construct patterns from elementary shapes. However, one distinctive characteristic of expert spatial thinking is that it typically involves imagining structures and processes that are much more complex than those contained in spatial ability items. There are essential questions, therefore, about how the ability to imagine simple objects such as cubes, and simple transformations such as rotations, scales up to such complex cognitive activities as imagining the structure and functioning of the digestive system or predicting the improvement of a hurricane.

A second distinctive characteristic of expert spatial thinking is that it increasingly involves using and interacting with external visual–spatial representations. Biologists, architects, and technicians have relied on printed diagrams such as cross sections, exploded views, and orthographic projections ever since the renaissance (Ferguson, 2001), meteorologists rely heavily on satellite and infrared images (Trafton & Hoffman, 2007), and chemists have developed several diverse ways of representing a molecule that facilitates different types of chemical problem solving (Stieff, 2007). Choosing the right external representation for a task can be an essential component of spatial thinking. Furthermore, with improvements in imaging technologies, computer graphics, and human–computer interaction, spatial thinking depends on the ability to interact effectively with instruments and powerful external visualizations. Today's meteorologists work with interactive systems in which they can add and subtract meteorological variables to weather maps at will, while also superimposing satellite and infrared imagery on these maps (Trafton & Hoffman, 2007). In these situations, adaptive spatial thinking also involves using interactive visualizations to their best advantage (Diezmann et al., 2000).

Spatial Cognition and Expert Performance in Chemistry

Stieff (2004, 2007) investigated expert and novice chemists' performances on a classic visual-spatial task, the mental rotation of three-dimensional figures. He used the classic Shepard and Metzler (1971) figures, which resemble three-dimensional blocks arranged in different positions. The participant's task is to decide whether a given block is a rotated version of a target. In addition, Stieff also included representations of three-dimensional chemical molecules. These were chemistry diagrams that are commonly taught in first- or second-year college chemistry classes.

There was a fascinating interaction between level of experience and the kinds of stimuli tested. Novice and expert chemists performed nearly identically on the Shepard and Metzler figures. In both groups, there was a strong, linear relation between degree of angular disparity and reaction time. This result is often taken as evidence for mental rotation; it takes more time to turn a stimulus that is rotated a great deal relative to the target than a stimulus that is rotated only slightly.

However, there was a strong expert-novice difference for the representations of three-dimensional symmetric chemistry molecules. The novices again showed the same relation between angular disparity and reaction time; the more the stimulus was rotated, the longer it took them to answer “same or different.” In contrast, the function relating angular disparity to reaction time was essentially flat in the data for the experts; the correlation was nearly zero. Experts apparently used a very different mental process to make judgments about the meaningful representations of real chemical molecules and about the meaningless Shepard and Metzler figures.

Mental Representations that Support Chemistry Expertise

As discussed above, chemistry experts do not seem to use mental rotation to solve problems regarding the configuration of a group of atom in a molecule. In some cases, factual or semantic knowledge will allow the STEM expert to avoid the use of spatial strategies. For example, Stieff’s (2007) work on novice expert differences in spatial ability reveals that experts relied substantially on semantic knowledge in a mental rotation task. The lack of correlation between angular disparity and experts’ reaction time suggest that they may have already known the answers to the questions. For example, knowing properties of molecules (e.g., that one molecule is an isomer of another molecule) would allow them to make the “same-different” judgment without need to try to mentally align the molecule with its enantiomer. Stieff (2004, 2007) confirmed this hypothesis in a series of protocol analyses of experts’ problem-solving. Semantic knowledge of chemical molecules allowed the experts to forego mental rotation.

Spatial Thinking and Organic Chemistry

Although the importance of spatial thinking may be most obvious in geology, it is equally important in other STEM fields. For example, a great deal of attention is devoted in chemistry to the study and behavior of isomers, which are compounds with identical molecular compositions, but different spatial configurations. A particularly important spatial property of isomers is chirality, or handedness. A molecule is chiral if its mirror image cannot be superimposed on itself through rotation, translation, or scaling. Molecules that are chiral opposites are called enantiomers. Chemistry teachers often use a classic analogy to explain chirality, namely, the spatial relation between a person's right and left hand. Although they share the same set of objects (fingers and thumbs), and the same set of relations among these objects, it is not possible to superimpose the left hand onto the right hand. Chemists and physicists have adopted this embodied metaphor, often referring to left- and right hand configurations of molecules.

Chirality matters greatly because although enantiomers share the same atoms, their spatial differences greatly affect how the isomers behave in chemical reactions. A classic example was the failure to distinguish between enantiomers of the Thalidomide molecule. One version of this drug acted as an effective treatment for morning sickness, and was prescribed in the early 1960s to many thousands of pregnant women. Unfortunately, its enantiomer caused very serious birth defects. Chemists and pharmacists did not realize that this spatial, but not structural, difference was important until it was too late (Fabro, Smith, & Williams, 1967). Both forms were included in the dispensed drug, which led to notoriously severe birth defects.

As many researchers (and students) have noted, learning to understand systems of spatial relations among molecules, and the representations of these molecules pictorially or with physical blocks, is one of the central challenges in learning chemistry.

Synthesis

The literature revealed the importance of spatial intelligence in understanding concepts in Chemistry specifically in Organic Chemistry. Since the content of this subject requires manipulation and rotation of different symbolic representation such as molecular structures and configurations, being able to manipulate objects is an essential skill in certain topics such as chirality and stereochemistry. As supported by the studies, full understanding of the different structures can be attained by the development of spatial skills and expertise. The interconnection of the four domains of spatial intelligence is vital for the development of spatial intelligence as a whole.

However, according to literature, the education sector accounts for the individuals with the least developed spatial intelligence and is worth investigating.

This body of literature are the existing supplement which account on why the relationship between spatial intelligence and performance of chemistry majors has been the topic of this study.

CHAPTER III

RESEARCH METHODOLOGY

This chapter presents the methods and procedures used by the researcher in the conduct and completion of this study. Specifically, it describes the research design, the sample used, the sampling technique employed, the source of data, the instruments used, data-gathering procedure, and statistical treatment applied in processing the gathered data.

Research Design

The study utilized a correlational study. It is a quantitative method of research in which the relationship between two or more quantitative variables from the same group of subjects are determined. The principal aim in employing this method is to describe the relationship between spatial intelligence and performance of Chemistry majors in Chemistry. The participants were considered as a single group and sets of scores from each participant represents each variable being studied (Creswell, 2008).

Research Procedure

Figure 2 shows the Research Paradigm of the study.

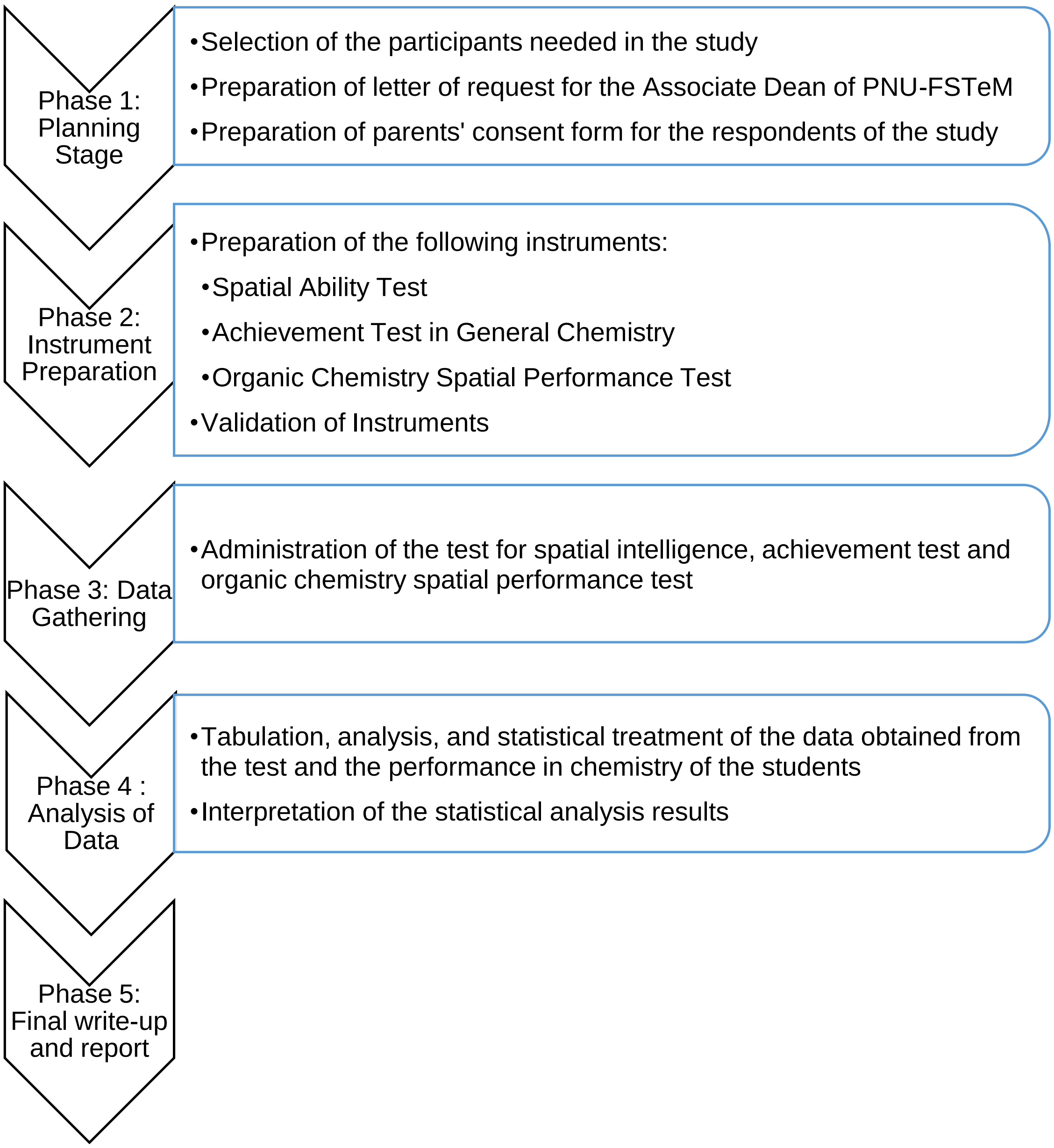

Figure 2: Flowchart of the Study

Phase 1: Planning Stage

In the planning stage, the selection of the respondents utilized the purposive sampling technique. This technique was employed because the respondents were Chemistry majors only and required respondents who had background in Chemistry. A Letter of request was sent to the PNU-FSTeM Associate Dean (see Appendix A) and a Parent's consent form were prepared for the students who participated in the study.

Participants of the Study

The respondents were the Bachelor of Secondary Education major in Chemistry and Bachelor of Science in Chemistry for Teachers students at Philippine Normal University. Forty three (43) respondents were taken from second to fourth year Chemistry majors in the second semester of school year 2013-2014. All respondents submitted the parents' consent form as a requirement for participation.

Phase 2: Instrument Preparation

Three instruments were used in this study: Spatial Ability Test, Achievement Test and Organic Chemistry Spatial Performance Test (See Appendix G and H). Validation (Appendix C) was done by three experts (Appendix D) for the face and construct validation of the Achievement Test and the Organic Chemistry Spatial Performance Test using the validation instruments on Appendix E and F. The ratings were interpreted based on the table 1:

Table 1
Interpretation of Percent Agreement

Range	Remark*
100.0	Perfect agreement
90.0 < P ≤ 100.0	Very high agreement
80.0 < P ≤ 90.0	High agreement
60.0 < P ≤ 80.0	Marked substantial agreement
40.0 < P ≤ 60.0	Moderate agreement
20.0 < P ≤ 40.0	Low agreement
0.0 < P ≤ 20.0	Negligible agreement
0.0	No agreement

*should at least be 30.0 (Gwet, 2010)

Research Instruments

A. Spatial Ability Test

The Spatial Ability Test that was used with the permission from the American Institute for Research (Appendix I) to measure the level of spatial intelligence of the respondents was adapted from Wai, Lubinski, and Benbow (2009). It was a 75-item test which was subdivided into four categories:

1. **Three-Dimensional Spatial Visualization** – This was a 16-item test which measured the ability of the respondents to visualize two-dimensional figures after they had been folded into three-dimensional figures.

2. **Two-Dimensional Spatial Visualization** – This was a 24-item test which measured the ability of the respondents to visualize two-dimensional figures when they were rotated or flipped in a plane.

3. **Mechanical Reasoning** – This was a 20-item test which measured the ability of the respondents to deduce relationships between gears, pulleys, and springs as well as their knowledge of the effects of basic physical forces, such as gravity.

4. **Abstract Reasoning** – This was a 15-item test constituting a nonverbal measure of finding logical relationships in sophisticated figure patterns.

To determine the composite score of the respondents, the weight presented below was used. It was derived by Humphreys and was also utilized by Wai.

Spatial Composite = 3.0 x [3-D Spatial Visualization] + 1.0 x [2-D Spatial Visualization] +1.5 x [Mechanical Reasoning] + 2.0 x [Abstract Reasoning]. (Wai et. al, 2009)

The scores of the respondents were interpreted in three different levels as presented in Table 2.

Table 2
Interpretation of Test Scores – Spatial Ability Test

Component	Range	Remark
Abstract Reasoning	$11 \leq$ Score ≤ 15	High
	$6 \leq$ Score ≤ 10	Average
	$0 \leq$ Score ≤ 5	Low
Mechanical Reasoning	$14 \leq$ Score ≤ 20	High
	$7 \leq$ Score ≤ 13	Average
	$0 \leq$ Score ≤ 6	Low
Manipulation in Two Dimensions	$17 \leq$ Score ≤ 24	High
	$9 \leq$ Score ≤ 16	Average
	$0 \leq$ Score ≤ 8	Low
Manipulation in Three Dimensions	$12 \leq$ Score ≤ 16	High
	$6 \leq$ Score ≤ 11	Average
	$0 \leq$ Score ≤ 5	Low
Composite Score	$89 \leq$ Score ≤ 132	High
	$45 \leq$ Score ≤ 88	Average
	$0 \leq$ Score ≤ 44	Low

B. Achievement Test in General Chemistry

The Achievement Test was used to measure the performance of the respondents. The test was used by Martinez (2005). The Achievement Test was a 50-item test composed of topics in general chemistry. A table of specification was made as a guide in constructing the test. The instrument underwent face and construct validation. The result of validation is shown in Table 3.

Table 3
Experts' Validation: Chemistry Achievement

Area	Acceptability			Agreement		
	Mean	SD	Remark	Percent	SE	Remark
A	3.67	0.500	Very High	33.3	0.000	Low
B	3.67	0.500	Very High	33.3	0.000	Low
C	3.67	0.500	Very High	33.3	0.000	Low
D	3.33	0.500	High	33.3	0.000	Low
E	3.67	0.500	Very High	33.3	0.000	Low
F	3.67	0.500	Very High	33.3	0.000	Low
G	3.33	0.500	High	33.3	0.000	Low
Overall	**3.65**	**0.499**	Very High	**33.3**	**0.000**	**Low**

The result of the validation suggests that the instrument had a very high acceptability with an overall mean of 3.65 which means that the validators believed that the instrument could measure what it intended to measure. The level of agreement among the validators was low (33.3%) but acceptable. It is above the 30 percent minimum to have an agreement (Gwet, 2010)

The test was graded as a one-to-one correspondence which means that every correct answer would correspond to one point. The result of the test was interpreted in four levels as presented in Table 4.

Table 4
Interpretation of Test Scores – Achievement Test

Range	Remark
$39 \leq \text{Score} \leq 50$	Excellent
$26 \leq \text{Score} \leq 38$	Good
$13 \leq \text{Score} \leq 25$	Fair
$0 \leq \text{Score} \leq 12$	Poor

C. Organic Chemistry Spatial Performance Test

The Organic Chemistry Spatial Achievement Test was also developed and validated to measure the performance of the respondents in Organic Chemistry. A table of specification was made as a guide in constructing the test. The test was composed of five open-ended questions in different topics in Organic Chemistry. It was graded using a scoring guide (Appendix K) with three points for content and three points for spatial skills for a maximum of six points per item making a total of 30 points. The instrument underwent face and construct validation. The result is shown in Table 5.

Table 5
Experts' Validation OCSPT with Scoring Guide

Area	Acceptability			Agreement		
	Mean	**SD**	**Remark**	**Percent**	**SE**	**Remark**
Obj	3.11	0.782	High	61.1	0.200	Marked substantial
Con	2.89	0.928	High	50.0	0.167	Moderate
Spat	3.44	0.726	High	72.2	0.111	Marked substantial
Struc	3.11	0.782	High	72.2	0.111	Marked substantial
Lang	3.44	0.527	High	33.3	0.000	Low
Use	3.44	0.726	High	66.7	0.167	Marked substantial
Rub	2.80	1.207	High	58.5	0.104	Moderate
Overall	**3.14**	**0.879**	High	**70.7**	**0.037**	Marked substantial

The result of the validation suggests that the instrument had a high acceptability with an overall mean of 3.14 which means that the validators believed that the instrument could serve its purpose. The validators also had a marked substantial level of agreement at 70.7%, well above the 30 percent minimum to have an agreement (Gwet, 2010).

The test was graded into two categories: concept and spatial skills. Each category had three points for each number, making a total of six points per test item. The result of the test was interpreted in four levels as presented in Table 6.

Table 6
Interpretation of Test Scores – OCSPT

Range	Remark
$23 \leq$ Score ≤ 30	Excellent
$15 \leq$ Score ≤ 22	Good
$7 \leq$ Score ≤ 14	Fair
$0 \leq$ Score ≤ 6	Poor

Phase 3: Data Gathering

A letter of request to the Associate Dean was prepared to use the Chemistry majors from second to fourth year to be the respondents in this study and scheduled for the test administration. A total of 43 respondents from second to fourth year submitted a reply from the parent's consent and were chosen to participate in the study. After the request to conduct the study was granted, the researcher administered the instruments to 43 respondents in the second semester of school year 2013-2014. The administration of the instruments to the selected respondents determined their level of spatial intelligence and achievement in chemistry.

Phase 4: Analysis of Data

Statistical Treatment

To describe the data, percentage, arithmetic mean, frequency distribution, standard deviation, ANOVA, multiple regression, p-level, and Pearson r correlation were utilized in the study. Arithmetic mean was used to describe the level of spatial intelligence and achievement in chemistry. P-level was used to determine the significance of the multiple intelligence components to chemistry achievement. Multiple regression was used to determine the best predictor of chemistry achievement among the variables identified.

The level of significance was interpreted using the following scale:

Table 7
Interpretation of p-level

Range	Remark
$p \geq 0.050$	not significant
$0.010 \leq p < 0.050$	significant
$0.001 \leq p < 0.010$	highly significant
$p < 0.001$	extremely significant

The scale above (Table 7) was used to interpret the significance of the relationships among the variables while the table below (Table 8) shows the interpretation of the coefficient of correlation.

Table 8
Interpretation of Pearson r

Range	Remark
$\lvert r \rvert = 1.000$	perfect rectilinear correlation
$0.900 < \lvert r \rvert < 1.000$	very high rectilinear correlation
$0.800 < \lvert r \rvert \leq 0.900$	high rectilinear correlation
$0.600 < \lvert r \rvert \leq 0.800$	marked substantial rectilinear correlation
$0.400 < \lvert r \rvert \leq 0.600$	moderate rectilinear correlation
$0.200 < \lvert r \rvert \leq 0.400$	low rectilinear correlation
$0.000 < \lvert r \rvert \leq 0.200$	negligible rectilinear correlation
$r = 0.000$	no rectilinear correlation

CHAPTER IV

RESULTS AND DISCUSSION

This chapter discusses the presentation, organization and analysis of the data gathered from the conduction of the research. The discussion follows the order in which the questions as presented in the statement of the problem.

Problem 1: What is the level of spatial intelligence of the students in the following domains?

a. Abstract Reasoning (ABS)
b. Mechanical Reasoning (MECH)
c. Manipulation in Two Dimensions (2D)
d. Manipulation in Three Dimensions (3D)

Table 9 shows the spatial intelligence respondents categorized in four domains.

Table 9
Spatial Intelligence of Respondents

Domain	Level	*f*	%	Mean	SD
ABS	High	33	76.7	12.39	1.088
	Average	10	23.3	8.80	1.317
		43			
MECH	High	4	9.3	16.25	1.708
	Average	32	74.4	9.38	1.497
	Low	7	16.3	4.71	0.951
		43			
2D	High	24	55.8	21.50	1.615
	Average	6	14.0	11.50	2.739
	Low	13	30.2	4.54	2.184
		43			
3D	High	11	25.6	12.64	0.674
	Average	28	65.1	8.64	1.660
	Low	4	9.3	4.75	0.500
		43			
COMP	High	9	20.9	103.33	8.667
	Average	34	79.1	73.68	12.891
		43			

The level of spatial intelligence is categorized into four domains namely: abstract reasoning (ABS), mechanical reasoning (MECH), manipulation in two dimensions (2D), and manipulation in three dimensions (3D).

In the abstract reasoning domain, 33 (76.7%) out of 43 respondents scored high with a mean of 12.39 while the rest of the respondents (10 or 23.3%) got an average score, with a mean of 8.80.

In the mechanical reasoning domain, 32 (74.4%) out of 43 respondents got an average score, with a mean of 9.38.

In the two dimensional manipulation domain, 24 (55.8%) out of 43 respondents scored high with a mean of 21.50.

In the three dimensional manipulation domain, 28 (65.1%) out of 43 respondents got an average score, with a mean of 8.64.

In the composite score domain, 34 (79.1%) out of 43 respondents got an average score, with a mean of 103.33.

The data show that the respondents had an average to high level of spatial intelligence in the individual domains and the majority of them got an average level of spatial intelligence in the composite score domain. Overall, they got an average score in spatial intelligence.

Interestingly, the majority of the respondents got a high level on both abstract reasoning and two dimensional manipulation. It could be a manifestation of the way the respondents' were trained from previous years as Wai et.al. (2012) had explained.

Problem 2: What is the chemistry performance of the students be in terms of the following?

a. Chemistry Achievement Test (ACH) scores

b. Organic Chemistry Spatial Performance Test (OCSPT) scores

Table 10
Scores in the Chemistry Achievement Test

Level	*f*	%	Mean	SD
Excellent	6	14.0	42.33	2.066
Good	35	81.4	32.51	3.364
Fair	2	4.7	24.50	0.707
All Levels	43	100.0	33.51	5.049

In the achievement test in chemistry, 6 (14.0%) out of the 43 respondents scored high with a mean of 42.33; 35 (81.4%) out of 43 respondents scored at a good level with a mean of 32.51; and 2 (4.7%) out of 43 respondents scored at fair level with a mean of 24.50.

The data show that the majority of the respondents had a good understanding of the concepts in chemistry. The result was expected as the respondents were all Chemistry majors and the test items were topics from General Chemistry which they have already taken.

Table 11 shows that the majority of the respondents had a low understanding of the concepts in organic chemistry and a poor ability in manipulating objects such as molecules in three dimensions.

Table 11
Scores in the Organic Chemistry Spatial Performance Test

Level	*f*	%	Mean	SD
High	2	4.7	16.00	1.414
Average	19	44.2	9.05	1.471
Low	22	51.2	3.27	1.778
All Levels	43	100	6.42	3.905

In the organic chemistry spatial performance test, 2 (4.7%) out of the 43 respondents scored high with a mean of 16.00; 19 (44.2%) out of 43 respondents scored at an average level with a mean of 9.05; and 22 (51.2%) out of 43 respondents scored at a low level with a mean of 3.27.

The data shows that while the majority of the respondents may have an average level of three dimensional skills, translating it to practical application in Organic Chemistry proved to be difficult for them.

Problem 3: Are there significant differences in the chemistry performance of students when they are categorized according to the above-mentioned spatial domains?

Table 12 shows how the different spatial intelligence domains and the OCSPT affect the respondents' performance in the achievement test in general chemistry.

Table 12
Differences in Chemistry Achievement by Relevant Variables

Variable	Level	*f*	%	Achievement Test			df	F	p	Remarks
				Mean	SD	Interpretation*				
ABS	High	33	76.7	33.88	5.302	Good	***1,41***	***0.746***	***0.393***	Not Significant
	Average	10	23.3	32.30	4.111	Good				
MECH	High	4	9.3	36.00	6.164	Good	***2,40***	***1.809***	***0.177***	Not Significant
	Average	32	74.4	33.84	5.087	Good				
	Low	7	16.3	30.57	3.309	Good				
2D	High	24	55.8	34.79	5.039	Good	***2,40***	***1.986***	***0.151***	Not Significant
	Average	6	14.0	32.83	4.446	Good				
	Low	13	30.2	31.46	4.926	Good				
3D	High	11	25.6	35.82	4.771	Good	***2,40***	***2.116***	***0.134***	Not Significant
	Average	28	65.1	32.39	4.969	Good				
	Low	4	9.3	35.00	4.967	Good				
COMP	High	9	20.9	37.22	4.944	Good	***1,41***	***7.030***	***0.011***	Significant
	Average	34	79.1	32.53	4.666	Good				
OCSPT	High	2	4.7	42.50	3.536	Excellent	***2,40***	***5.910***	***0.006***	Highly Significant
	Average	19	44.2	34.53	4.208	Good				
	Low	22	51.2	31.82	4.856	Good				

*Based on Mean

The data revealed that only the OCSPT and the composite score of the spatial intelligence skill test got a significant result. This suggests that the only the OCSPT and the composite score got an impact on the achievement of the respondents in chemistry.

Table 13 shows the correlation between the achievement and the variables of the study. As exhibited, abstract reasoning had a correlation value of 0.286 and a *p* value of 0.063 which could be interpreted as low positive correlation and insignificant; mechanical reasoning had a correlation value of 0.346 and a *p* value of 0.023 which could be interpreted as low positive correlation and insignificant; manipulation in two dimensions had a correlation value of 0.314 and a *p* value of 0.040 which could be interpreted as low positive correlation and insignificant; three dimensional manipulation had a correlation value of 0.176 and a *p* value of 0.259 which could be interpreted as negligible positive correlation and insignificant; composite score has a correlation value of 0.388 and a *p* value of 0.010 which could be interpreted as low positive correlation and significant; and the organic chemistry spatial performance test questions had a correlation value of 0.523 and a *p* value of 0.000 which could be interpreted as moderate positive correlation and extremely significant.

Table 13
Correlation between Achievement and Relevant Variables

N = 43

Variable	r*	P	Remark
ABS	0.286	0.063	low positive/negative rectilinear correlation; not significant
MECH	0.346	0.023	low positive/negative rectilinear correlation; significant
2D	0.314	0.040	low positive/negative rectilinear correlation; significant
3D	0.176	0.259	negligible positive/negative rectilinear correlation; not significant
COMP	0.388	0.010	low positive/negative rectilinear correlation; significant
OCSPT	0.523	0.000	moderate positive/negative rectilinear correlation; extremely significant

$^{*}r_{0.05(2),\,41} = 0.301$

Table 13 shows that only the OCSPT questions and the chemistry achievement had a moderate positive correlation. Both the composite scores and OCSPT questions showed significant correlation with the chemistry achievement.

Table 14
Forecasting Efficiency of Relevant Variables

Variable	r^2, %	1- r^2, %	E, %
ABS	8.2	91.8	4.2
MECH	12.0	88.0	6.2
2D	9.9	90.1	5.1
3D	3.1	96.9	1.6
COMP	15.0	85.0	7.8
OCSPT	27.3	72.7	14.7

Table 14 shows the forecasting efficiency of the variables. The 8.2% of the variation in the achievement scores could be explained by abstract reasoning and 91.8% of the variation in the achievement test scores could not be accounted for by abstract reasoning.

The 12.0% of the variation in the achievement scores could be explained by mechanical reasoning and 88.0% of the variation in the achievement scores could not be accounted for by mechanical reasoning.

The 9.9% of the variation in the achievement scores could be explained by the two dimensional manipulation and 90.1% of the variation in the achievement scores could not be accounted for by a by two dimensional manipulation.

The 3.1% of the variation in the achievement scores could be explained by three dimensional manipulation and 96.9% of the variation in the achievement scores could not be accounted for by a by three dimensional manipulation.

The 15.0% of the variation in the achievement scores could be explained by the composite scores and 85.0% of the variation in the achievement scores could not be accounted for by the composite scores.

The 27.3% of the variation in the achievement scores could be explained by the OCSPT questions and 72.7% of the variation in the achievement scores could not be accounted for by the OCSPT questions.

Problem 4: Are there significant relationship between spatial intelligence and chemistry performance of the students?

Table 15 shows the correlation values of the variables and the chemistry achievement.

Table 15
Correlation Matrix: Achievement Test vs Relative Variables

Variable	ACH	ABS	MECH	2D	3D
ACH					
ABS	0.286				
MECH	0.346	0.310			
2D	0.314	0.194	0.310		
3D	0.176	0.342	**0.481**	0.202	
OCSPT	**0.523**	0.179	**0.415**	**0.404**	0.267

Noticeably, the three dimensional manipulation is correlated with the mechanical reasoning, with a correlation value of 0.481. The organic chemistry spatial achievement test is correlated with achievement, mechanical reasoning, and two dimensional manipulation with correlation values of 0.523, 0.415, and 0.404 respectively.

It can be inferred that because of high correlation value, organic spatial achievement test is a good predictor of chemistry performance. Organic spatial performance is also correlated with the majority of the variables. It can be inferred from the data that mechanical reasoning and two dimensional manipulation were the components of spatial intelligence that have a significant correlation with OCSPT and Chemistry achievement.

Problem 5: Which area of spatial intelligence serves as the best predictor of chemistry performance?

The results of regression ANOVA with five degrees of freedom had the F-value of 3.646 and p-level of 0.009 with a high level of significance (Table 16).

Table 16
Regression ANOVA: Achievement Test by Relevant Variables

Sources of Variation	Sums of Squares	Df	Mean Squares	F	p-level	Remarks
Regression	353.402	5	70.680	3.646	0.009	Highly Significant
Residual	717.342	37	19.388			
Total	1070.744					

Correlation and regression ANOVA were computed to determine any relationship between the achievement test and various potential predictors. Table 16 summarizes the descriptive statistics and analysis results. Based on the results, one predictor registered high level of significance with the chemistry performance.

Table 17 shows the detailed analysis of the predictors and their significance in chemistry performance.

Table 17
Regression Summary: Achievement Test by Relevant Variables

Predictors	Beta	Std. Error of Beta	B	Std. Error Of B	t(37)	p-level	Remarks
Intercept			23.149	4.321	5.357	0.000	
ABS	0.181	0.146	0.481	0.387	1.241	0.222	Not Significant
MECH	0.124	0.166	0.197	0.264	0.746	0.461	Not Significant
2D	0.084	0.150	0.053	0.095	0.562	0.578	Not Significant
3D	0.076	0.158	-0.144	0.300	-0.481	0.634	Not Significant
OCSPT	0.425	0.156	0.549	0.202	2.717	**0.010**	**Significant**
N=43	R= .575	R^2= .330 SE= 4.4031					

The five predictors for chemistry achievement—abstract reasoning, mechanical reasoning, manipulation in two dimensions manipulation in three dimensions, and organic chemistry spatial achievement test had p-levels of 0.222, 0.461, 0.578, 0.634 and 0.010 respectively. As exhibited in Table 17, only the organic chemistry spatial achievement test performance showed significance while the other predictors showed no significance to chemistry achievement. Results also showed an R value of 0.575 and an R^2 value of 0.330.

The regression model with all five predictors resulted in an R^2 value of 0.330. The analytic and quantitative scale of the organic chemistry spatial achievement test had a significant positive regression weights, indicating that the predictor affect the respondents' achievement in chemistry while the other predictors do not affect at all the respondents' achievement in chemistry.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of the findings, conclusions and recommendations relative to the problem of the study.

General Summary

The study was conducted to determine the relationship between spatial intelligence and performance in Chemistry. This study determined the following: the spatial intelligence profile of the students in the Abstract Reasoning, Mechanical Reasoning, Manipulation in Two Dimensions, and Manipulation in Three Dimensions domains of spatial intelligence, the chemistry performance of the students be in terms of the Chemistry Achievement Test and Organic Chemistry Spatial Performance Test (OCSPT) scores, the significant differences in the chemistry performance of students, the significant relationship between the spatial intelligence domains and chemistry performance of the students and the best predictor of chemistry performance of students.

The respondents of the study were taken from the Bachelor of Secondary Education major in Chemistry and Bachelor of Science in Chemistry for Teachers students from second to fourth year level at Philippine Normal University who were enrolled in the second semester of school year 2013-2014. Purposive sampling technique was employed because the study required respondents who had background in Chemistry and the sample was comprised of a total of 43 students.

A correlational research design was employed to determine the relationship between spatial intelligence and performance in chemistry of the students.

Three instruments were used in this study namely, Spatial Ability Test, Achievement Test and Organic Chemistry Spatial Performance Test. The two latter instruments were validated by three experts using the checklist provided by the researcher.

The data obtained in the study were analysed using percentage, arithmetic mean, frequency distribution, standard deviation, ANOVA, multiple regression, p-level, and Pearson r correlation were utilized in the study. Arithmetic mean was used to describe the level of spatial intelligence and achievement in chemistry. P-level was used to determine the significance of the multiple intelligence components to chemistry achievement. Multiple regression was used to determine the best predictor of chemistry achievement among the variables identified.

Summary of Findings

Based on the data gathered and analyzed, the following findings were made:

1. In the abstract reasoning domain, 76.7% of the respondents scored high with a mean of 12.39. In the mechanical reasoning domain, 74.4% of the

respondents got an average score, with a mean of 9.38. In the two dimensional manipulation domain, 55.8% of the respondents scored high with a mean of 21.50. In the three dimensional manipulation domain, 65.1% of the respondents got an average score, with a mean of 8.64. In the composite score, 79.1% of the respondents got an average score, with a mean of 103.33.

2. In the achievement test in chemistry, 81.4% of the respondents scored at a good level with a mean of 32.51. In the organic chemistry spatial performance test, 51.2% of the respondents scored at a low level with a mean of 3.27.
3. The data revealed with a *p*-level of 0.006 and 0.011, only the OCSPT and the composite score got a significant result.

4. The three dimensional manipulation domain is correlated with mechanical reasoning, with a correlation value of 0.481. The organic chemistry spatial achievement test is correlated with achievement, mechanical reasoning, and two dimensional manipulation with correlation values of 0.523, 0.415, and 0.404 respectively.

5. The results of regression ANOVA with five degrees of freedom showed a p-level of 0.009 with a high level of significance.

Conclusions

In light of the findings, the following conclusions were drawn:

1. The majority of the respondents had a high level of abstract reasoning and two dimensional manipulation skills, an average level of mechanical and three dimensional manipulation skills, and an average level of spatial intelligence. Also, the majority of the respondents showed a low to average level of skills in the organic chemistry spatial achievement test.

2. Generally, the respondents have a high level of achievement in Chemistry. On the other hand, based on organic chemistry spatial achievement test results, their achievement ranges from low to average.

3. There is a significant difference between the composite score in the spatial intelligence test and in the achievement of the respondents. There is also an extreme level of significance between the respondents' scores in the organic chemistry spatial achievement test and in their achievement test scores.

4. There is a low positive correlation between the spatial intelligence of the respondents and their achievement in Chemistry. There is also a moderate positive correlation between the organic chemistry spatial achievement test performance and the Chemistry achievement of the respondents.

5. The organic chemistry spatial achievement test performance of the respondents is the best predictor of their Chemistry performance.

Recommendations

Based on the findings and the conclusions made, the following are hereby recommended:

1. For comparison of the self and measured intelligence evaluation, it is recommended that, in future studies, the multiple intelligence profiles of the students be included in conjunction with direct spatial intelligence measurement.

2. To determine the trend of spatial intelligence among Chemistry majors at PNU across batches, it is recommended that data be collected from Chemistry majors from different levels.

3. To broaden the description of spatial intelligence especially in teacher education, it is recommended that non-Chemistry majors be included in future studies.

4. For a more accurate measurement of the chemistry achievement of the students, it is recommended that multiple instruments and sources be used in future studies.

5. The study found out a low positive correlation between the spatial intelligence and the Chemistry performance of the respondents. For a more conclusive result, the use of a bigger sample size is recommended

6. The study showed a significant correlation between mechanical reasoning and two dimensional manipulation with OCSPT and Chemistry achievement. It is recommended that the said spatial intelligence components be incorporated to the instrument for the selection of future Chemistry majors.

7. The study showed a positive result of the OCSPT. Further development and utilization of the instrument in teaching Organic Chemistry is recommended.

References

Achter, J. A., Lubinski, D., Benbow, C. P., & Eftekhari-Sanjani, H. (1999). Assessing vocational preferences among gifted adolescents adds incremental validity to abilities: A discriminant analysis of educational outcomes over a 10-year interval. Journal of Educational Psychology, 91, 777–786.

Anastasi, A. (1968) Psychological Testing, (3rd Ed). New York: Macmillan.

Ault, C. R. (1994) Research on problem solving: Earth science, in D. L. Gabel (Ed.) Handbook of Research on Science Teaching and Learning (pp. 269-283). New York: Macmillan

Berry, J. W. (1976) Human Ecology and Cognitive Style: Comparative Studies in Cultural and Psychological Adaptation. New York: Sage-Halsted.

Bertel, S. (2009). Spatial Structures and Visual Attention in Diagrammatic Reasoning. Unpublished Doctoral thesis, University of Bremen, Germany

Carter, C. S., Larussa, M. A., & Bodner, G. M. (1987) A study of two measures of spatial ability as predictors of success in different levels of general chemistry, Journal of Research in Science Teaching, 24(7), pp. 645-657.

Clements, M. A. (1981) Visual imagery and school mathematics, For the Learning of Mathematics, 2, pp. 2-9.

Cohen, A. (2011). Improving Geographic Literacy: The Effects of Motivation, Project-Based Instruction, and Collaborative Learning. Unpublished master's thesis, University of California, San Diego

Creswell, J. (2008). Educational research: Planning, conducting, and evaluating quantitative and qualitative research. New Jersey: Pearson: Merrill Prentice Hall.

Diezmann, Carmel M and Watters, James J (2000) Identifying and supporting spatial intelligence in young children. Contemporary Issues in Early Childhood 1(3):299-313.

DuBois, P. H. (1966) A test-dominated society: China 1115B.C. - 1905A.D., in A. Anastasi (Ed.) Testing Problems in Perspective (pp. 29-36). Washington: American Council on Education.

Einstein, A., quoted in J Hadamard, The Psychology of Invention in the Mathematical Field, Princeton, NJ: Princeton University Press, 1949.

Eliot, J., & Smith, I. M. (1983). An international directory of spatial tests. Windsor, Berkshire: NFER-Nelson.

Eliot, J. (1987) Models of Psychological Space: Psychometric, Developmental and Experimental Approaches. New York: Springer Verlag.

Ferguson, E. S. (2001). Engineering and the mind's eye. Cambridge: MIT Press.

Fabro, S., Smith, R., & Williams, R. (1967). Toxicity and teratogenicity of optical isomers of thaidomide. Nature, 215, 296.

Fennema, E., & Tartre, L. A. (1985). The use of spatial visualisation in mathematics by girls and boys, Journal of Research in Mathematics Education, 16, pp. 187-206.

Gabel, D. (1999). Improving Teaching and Learning through Chemistry Education Research: A Look to the Future, Journal of Chemical Education, 76(4), 548-554

Gabel, D. L., & Bunce, D. M. (1994) Research on problem solving: Chemistry in D. L. Gabel (Ed.) Handbook of Research on Science Teaching and Learning (pp. 301-326). New York: Macmillan

Gardner, H. (1983) Frames of Mind: The Theory of Multiple Intelligences. New York: Basic Books.

Gardner, H. (1993a) Multiple Intelligences: The Theory in Practice. New York: Basic Books. 12

Gardner, H. (1993b) Creating Minds: An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi. New York: Basic Books.

Gardner, H. (1997) Extraordinary Minds. New York: Basic Books.

Gleick, J. (1992) Genius: Richard Feynman and Modern Physics. London: Abacus.

Gohm, C. L., Humphreys, L. G., & Yao, G. (1998). Underachievement among spatially gifted students. American Educational Research Journal, 35, 515–531.

Goldman, A. I. (1986) Epistemology and Cognition. Cambridge, MA: Harvard University Press.

Guay, R. B. & McDaniel, E. D. (1977). The relationship between mathematics achievement and spatial abilities among elementary school children, Journal for Research in Mathematics Education, 8, pp. 210-215.

Gwet, K. L. (2010). Handbook of Inter-Rater Reliability (2nd Edition). Advanced Analytics, LLC. Maryland, USA.

Gwet, K. L. (2011a). The Practical Guide to Statistics, Advanced Analytics, LLC. Maryland, USA.

Hegarty, M. (1992). Mental animation: Inferring motion from static diagrams of mechanical systems. Journal of Experimental Psychology: Learning, Memory and Cognition, 18(5),1084–1102.

Hegarty, M. (2004). Mechanical reasoning as mental simulation. Trends in Cognitive Sciences, 8, 280–285.

Hegarty, M., Canham, M., & Fabrikant, S. I. (in press). Thinking about the weather: How display salience and knowledge affect performance in a graphic inference task. Journal of Experimental Psychology: Learning, Memory and Cognition.

Hegarty, M., & Waller, D. A. (2005). Individual differences in spatial abilities. In P. Shah & A. Miyake (Eds.), The Cambridge handbook of visuo-spatial thinking (pp. 121–169). New York: Cambridge University Press.

Hegarty, M., Keehner, M., Cohen, C., Montello, D. R., & Lippa, Y. (2007). The role of spatial cognition in medicine: Applications for selecting and training professionals. In G. Allen (Ed.), applied spatial cognition. Mahwah: Lawrence Erlbaum Associates.

Hutchins, E. (1983) Understanding Micronesian navigation, in D. Gentner & A. L Stevens (Eds.), Mental Models (pp. 191-225). Hillsdale, NJ: Erlbaum.

Kayhan, E. (2005). Investigation of High School Students' Spatial Ability. Unpublished master's thesis, Middle East Technical University, Turkey

Kearins, J. M. (1986) Visual spatial memory in Aboriginal and white Australian children, Australian Journal of Psychology, 38, pp. 203-214.

Keehner, M., Lippa, Y., Montello, D. R., Tendick, F., & Hegarty, M. (2006). Learning a spatial skill for surgery: How the contributions of abilities change with practice. Applied Cognitive Psychology, 20, 487–503.

Keehner, M., Hegarty, M., Cohen, C. A., Khooshabeh, P., & Montello, D. R. (2008). Spatial reasoning with external visualizations: What matters is what you see, not whether you interact. Cognitive Science, 32, 1099–1132.

Kozhevnikov, M., Motes, M., & Hegarty, M. (2007). Spatial visualization in physics problem solving. Cognitive Science, 31, 549–579.

Krutetskii, V. A. (1976). The Psychology of Mathematical Abilities in School Children. Chicago: University of Chicago Press.

Lohman, D. F., Pellegrino, J. W. Alderton, D. L. & Regian, J. W. (1987) Individual differences in spatial abilities, in S. H. Irvine & S. E. Newstead, (Eds.) Intelligence and Cognition, Dordrich: Kluwer.

Lohman, D. F. (1988). Spatial abilities as traits, processes, and knowledge. In R. J. Sternberg (Ed.), Advances in the Psychology of Human Intelligence (pp. 181–248). Hillsdale: Erlbaum.

Lord, T. R. (1987) Spatial teaching, The Science Teacher, 54(2), 32-34.

Lubinski, D. (2010). Spatial ability and STEM: A sleeping giant for talent identification and development. Personality and Individual Differences, 49, 344-351. Special Issue: Festschrift for Thomas J. Bouchard, Jr., Guest Edited by Matthew McGue & Wendy Johnson.

Luria A. (1973). The Working Brain: Introduction to Neuropsychology. Hammondsworth: Penguin.

Martinez, F. (2005). Multiple Intelligences of College Chemistry Students, Their Relationship to Chemistry Achievement and Program of Study.

McGee, M. G. (1979) Human spatial abilities: Psychometric studies and environmental, genetic, hormonal and neurological influences, Psychological Bulletin, 5, pp. 889-918.

Mitchell, C. E., & Burton, G. M. (1984) Developing spatial ability in young children, School Science and Mathematics, 84(5), pp. 395-405.

Pallrand, G. J., & Seeber, F. (1984) Spatial ability and achievement in introductory physics, Journal of Research in Science Teaching, 21, pp. 507-516.

Pellegrino, J. W., & Kail, R. V. (1982). Process analyses of spatial aptitude. In R. J. Sternberg (Ed.), Advances in the psychology of human intelligence, Vol. 1 (pp. 311–365). Hillsdale: Erlbaum

Pribyl, J. R., & Bodner, G. M. (1987) Spatial ability and its role in organic chemistry: a study of four organic courses, Journal of Research in Science Teaching, 24, pp. 229-240.

Rogers, E. (1995) A cognitive theory of visual interaction, in J. Glasgow, N. H. Narayanan, & B. Chandrasekavan (Eds.) Diagrammatic Reasoning: Cognitive and Computational Perspectives (pp. 481-500). Cambridge UK: MIT Press.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. Science, 171(3972), 701-703.

Siemonkowski, F., & MacKnight, F. (1971) Spatial cognition: Success prognosticator in college science courses, Journal of College Science Teaching, 1, pp. 50-59.

Smith, I. M. (1964). Spatial ability: Its educational and social significance. San Diego: Knapp.

Sternberg, R. J. (1990) Metaphors of Mind: Conceptions of the Nature of Intelligence. Cambridge: Cambridge University Press.

Stieff, M. (2004). A localized model of spatial cognition in chemistry. (Doctoral dissertation). Northwestern University, Evanston, IL.

Stieff, M. (2007). Mental rotation and diagrammatic reasoning in science. Learning and Instruction, 17, 219–234.

Stull, A. T., Hegarty, M., & Mayer, R. E. (2009). Orientation references: Getting a handle on spatial learning. Journal of Educational Psychology, 101, 803–816.

Sukumar, K. (2013). Correlating the Purdue Spatial Visualization Test with the Wonderlic Personnel Test for American Football Players. Unpublished master's thesis, Purdue University, Indiana.

Trafton, J. G., & Hoffman, R. R. (2007). Computer-aided visualization in meteorology. In R. R. Hoffman (Ed.), Expertise out of context: Proceedings of the sixth international conference on naturalistic decision making (pp. 337–358). New York: CRC Press.

Uttal, D & Cohen C. (2012). Spatial Thinking and STEM Education: When, Why, and How? Psychology of Learning and Motivation, Volume 57

Wai, J., Lubinski, D., & Benbow, C. P. (2005). Creativity and occupational accomplishments among intellectually precocious youth: An age 13 to age 33 longitudinal study. Journal of Educational Psychology, 94, 785–794.

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over fifty years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology, 101,* 817-835.

Wasserman, S. (1992) Serious play in the classroom: How messing around can win you the Nobel Prize, Early Childhood Education (Annual ed., pp. 202-208). Wheaton MD: Association for Childhood Education International.

Webb, R. M., Lubinski, D., & Benbow, C. P. (2007). Spatial ability: A neglected dimension in talent searches for intellectually precocious youth. *Journal of Educational Psychology, 99,* 397-420.

Internet Sources

Chapman, A. (2003). Howard Gardner's multiple intelligences. Retrieved April 22, 2014 fromhttp://www.business balls.com/howardgardnermultipleintelligences.htm#multipleintelligences tests

Helding, L. (2009). Howards Gardner's theory of multiple intelligences. *Journal of Singing 66.2* 193. Retrieved April 22, 2014 from http://go.galegroup.com.pc181.lib.rochester.edu/ps/i.do?action=interpret&id=GALE%7CA2218 50666& v=2.1&u=nysl_ro_rochstru&it=r&p=AONE&sw=w&authCount=1

Gardner, H. (2011). The Theory of Multiple Intelligences: As Psychology, As Education, As Social Science. Retrieved April 29, 2014 from http://howardgardner.com/multiple-intelligences/

Kelly, M. (n.d.). Spatial Intelligence - Profile & Introduction. *About.com Secondary Education*. Retrieved June 12, 2013, from http://712educators.about.com/od/multipleint/p/Spatial-Intelligence.htm

Lubinski, D., Park, G., & Benbow, C. (2011, November 2). Recognizing Spatial Intelligence. *Scientific American Global RSS*. Retrieved July 23, 2013, from http://www.scientificamerican.com/article/recognizing-spatial-intel/

Philippine Normal University. (n.d.).*Philippine Normal University*. Retrieved June 1, 2013, from http://pnu.edu.ph/page/brief_history.php

Smith, M. (2002,2008). Howard Gardner, multiple intelligences and education. Retreived April 18, 2014 from http://infed.org/mobi/howard-gardner-multiple-intelligences-and-education

Wai, J. (2012, March 11). Why Don't We Value Spatial Intelligence?. *Psychology Today: Health, Help, Happiness + Find a Therapist*. Retrieved April 1, 2013, from http://www.psychologytoday.com/blog/finding-the-next-einstein/201203/why-dont-we-value-spatial-intelligence

Waters J. (n.d). Correlational Research Guidelines. Retrieved August 29, 2014 from http://www.capilanou.ca/psychology/student-resources/research-guidelines/Correlational-Research-Guidelines/

APPENDICES

Appendix A

LETTER TO THE ASSOCIATE DEAN

29 September 2013

Dr. Gladys Nivera
Associate Dean, FSTeM
Philippine Normal University
Taft Avenue, Manila

Dear Madam:

It is my pleasure to inform you that I am currently on the data gathering stage of my graduate thesis **Level of Spatial Intelligence and Performance of Chemistry Majors in Philippine Normal University** at the College of Graduate Studies Philippine Normal University, Manila.

This study seeks to determine and correlates the relationship of student's level of spatial intelligence and their academic performance in Chemistry.

In line with this, I am asking for your permission to allow me to gather data from the Chemistry majors who already taken General Chemistry, on **October 9, 2013** from **8:00 a.m. to 12:00 noon.**

Rest assured that I would have coordinate with the concerned teachers for smooth and orderly administration of the instruments.

Your favorable and immediate response to their matter is highly appreciated.

Thank you so much!

Very truly yours,

LARRY F. TENGCO
Researcher

Noted:

Dr. Virgil Duad
Faculty, FSTeM
Philippine Normal University

Vic Marie I. Camacho
Senior Program Manager, RCTQ
Philippine Normal University

Appendix B

PARENT'S CONSENT FORM

25 September 2013

Dear Parent:

I am Larry F. Tengco, a graduate student from the Philippine Normal University under the program Master of Arts Major in Chemistry. I am currently writing my thesis paper as the terminal requirement prior to my graduation this second semester, school year 2013-2014.

My graduate thesis looks into the **Level of Spatial Intelligence and Performance of Chemistry Majors in Philippine Normal University.** It determines and correlates the relationship of student's level of spatial intelligence to their academic performance in Chemistry.

I am happy to inform you that your son/daughter was chosen to be one the respondents in the study. As a respondent, your son/daughter will take various tests in Chemistry. This study will be done within the University. Rest assured the administration of the instruments will not interfere with the scheduled classes of your son/daughter. The administration of the instruments is permitted by the university authorities.

In this regard, I am seeking for your permission to allow your child to participate in this activity. The results of the tests will be kept confidential and will be used for the aforementioned research only.

Hoping for your cooperation and support.

Thank you very much

Respectfully,

Larry F. Tengco

Researcher

Noted:

Dr. Gladys Nivera
Associate Dean, FSTeM
Philippine Normal University

PERMIT TO PARTICIPATE

____ I will allow my son/daughter/ward ____ I will not allow my son/daughter/ward

to participate in this study titled "**Level of Spatial Intelligence and Performance of Chemistry Majors in Philippine Normal University.**"

____ ________________________________

Signature over Printed Name of Parent/Guardian Date

Appendix C

LETTER TO VALIDATORS

Dear Sir/Madam,

Greetings!

I am Larry F. Tengco, a graduate student from the Philippine Normal University under the program Master of Arts Major in Chemistry. Having completed the academic requirements of the said course, I am currently writing my thesis paper as the terminal prerequisite prior to my commencement this first semester of the School Year 2013-2014.

My graduate thesis looks at the **Level of Spatial Intelligence and Performance of Chemistry Majors in Philippine Normal University** which determines and correlates the relationship of student's level of spatial intelligence to their academic performance in Chemistry.

In line with the completion of the investigation, I will be utilizing different instruments to address its objectives and come up with the reliable data and results. It is in this light that I would like to ask for your assistance in validating my instrument and provide comments and suggestions for the improvement of the study. I believe that your expertise and inclination on the field is the most reliable source of ideas and supplements deemed necessary for the accuracy and sustainability of the research instruments to be used.

Attached are the following: the instruments used for the conduction of the study and the rubrics to be used for assessment with corresponding validation checklists.

Thank you for taking time to complete the items on the validation checklist.

Very truly yours,

Larry F. Tengco

Researcher

Noted:

Dr. Virgil Duad
Faculty, FSTeM
Philippine Normal University

Vic Marie I. Camacho
Senior Program Manager, RCTQ
Philippine Normal University

Appendix D
PROFILE OF EVALUATORS

Evaluator	Educational Attainment	Position	Institution
1	MST- Chemistry	Assoc. Prof. III	TUP- Manila
2	MS	Asst. Prof. III	PNU- Manila
3	MA Science Education Major in Chemistry	Instructor	TUP- Manila

Appendix E

RUBRICS FOR CONTENT AND FACE VALIDITY OF THE ACHIEVEMENT TEST

Evaluator ____________________
Educational Attainment ____________________
Position ____________________
Institution ____________________

DIRECTIONS: Below is a list of different criteria for evaluating the achievement test in chemistry using mathematical concepts. Please rate each item by ticking (/) the corresponding equivalent on the four point scale.

Description	Scale
All indicators are observed	4
Most of the indicators are observed	3
Some of the indicators are observed	2
No Indicators observed	1

EVALUATION CRITERIA	RATE			
A. CONTENT	**4**	**3**	**2**	**1**
a. Topics being measured are in the scope of the curriculum.				
b. Items are relevant to the topic/subject being measured.				
c. There is only one correct answer per question.				
B. ITEMS				
a. Number of items per topic is sufficiently distributed				
b. Number of items are correctly assigned in the Table of Specifications.				
c. Number of items are sufficient to measure achievement of students in the subject being measured.				
C. LEVEL OF DIFFICULTY				
a. There are no hints in each question.				
b. Level of difficulty is parallel to the students' academic level				
c. Indicates the level of performance which increases with equal increment that is parallel to the students' skill level.				
D. STRUCTURE				
a. Has a clear heading such as the date, name, and title.				

b. Has a clear layout such as margins, spaces in between questions and choices.				
c. Font size, style, letters/numbers and spacing are uniform throughout the instrument.				
E. INSTRUCTIONS				
a. Instructions are well constructed				
b. Includes clear instructions that are easy to follow.				
c. Instructions are appropriate for the type of test.				
F. LANGUAGE				
a. Is free of any errors in punctuation.				
b. Contains correct capitalization of words.				
c. Free from grammatical errors.				
G. ETHICAL/SOCIAL				
a. Contains relevant or associated texts that are free from offensive language.				
b. Is free from cultural discrimination.				
c. Has equal reference to both male and female gender in the test questions.				

COMMENTS AND SUGGESTIONS:

____

____

____

____

____

____

Signature over Printed Name of the Evaluator

Appendix F

RUBRICS FOR VALIDITY OF THE ORGANIC CHEMISTRY SPATIAL PERFORMANCE TEST

Evaluator ______________________________
Educational Attainment ______________________________
Position ______________________________
Institution ______________________________

DIRECTIONS: Below is a list of different criteria for evaluating the achievement test in chemistry using mathematical concepts. Please rate each item by ticking (/) the corresponding equivalent on the four point scale.

Scale	Descriptive Rating	Description
4	Strongly Agree	Complete evidence of the indicator is observed
3	Agree	Fairly complete evidence of the indicator is observed
2	Disagree	Very little evidence of the indicator is observed
1	Strongly disagree	No evidence of the indicator is observed

A. The **OBJECTIVES** of the test:

	4	**3**	**2**	**1**
1.				
2.				
3.				
4.				

COMMENTS AND SUGGESTIONS:

____
____
____

B. The **CONTENT** of the test:

	4	**3**	**2**	**1**
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

COMMENTS AND SUGGESTIONS:

___

___

___

C. The **STRUCTURE** of the test:

	4	**3**	**2**	**1**
1.				
2.				
3.				
4.				

COMMENTS AND SUGGESTIONS:

D. The **LANGUAGE** of the test:

	4	**3**	**2**	**1**
1.				
2.				
3.				
4.				

COMMENTS AND SUGGESTIONS:

E. The test is **USEFUL** in terms of:

	4	**3**	**2**	**1**
1.				
2.				
3.				
4.				

COMMENTS AND SUGGESTIONS:

Signature over Printed Name of the Evaluator

Appendix G

ACHIEVEMENT TEST IN GENERAL CHEMISTRY

PART A. MULTIPLE CHOICE

Directions: This is a test of your knowledge in general chemistry. Read each question carefully and decide which the best answer is. In your answer sheet, blacken the circle that corresponds to your answer.

1. Which of the following does chemistry emphasize?

   a. The changes and composition substances will undergo that are necessary to cause or prevent these changes
   b. Composition and structure of these substances
   c. Properties of substances
   d. All of the above

2. What do you call the process of recording and describing the experiment in scientific language, using shorthand symbols and equations?

   a. Observations c. Representation
   b. Interpretation d. Discussion

3. Which of the following is a systematic approach to research?

   a. Discovery method c. Experimental method
   b. Inquiry method d. Scientific method

4. Which of the following is the equivalent to the normal body temperature of 37 °C?

   a. 131 K b. 310 K c. 65.27 d. 69.85 mm

5. What do you call anything that occupies space and has mass?

   a. Force b. matter c. energy d. density

6. Which of the following is a characteristic of a solution?

a. Variable composition
b. Constant composition
c. Definite composition
d. Unique composition

7. When sugar is heated, a black substance that is not sweet is formed. This is an example of what change in matter?

a. Chemical change
b. Physical change
c. Definite change
d. Sublimation

8. Which of the following process illustrates physical change?

a. Ripening of fruit
b. Digestion of food
c. Salt dissolving in water
d. Sugar becoming a carbon and water

9. Who postulated the atomic theory of matter?

a. Chadwick
b. Dalton
c. Newland
d. Newton

10. A metallic element is one which reflects heat and light readily and conducts heat and electricity remarkably well. What is the most metallic element?

a. Selenium ($4p^4$)
b. Osmium ($5d^6$)
c. Silicon ($3p^2$)
d. Cesium ($6s^1$)

11. The head to head overlap between the p orbitals of atoms results in the formation of what type of bond?

a. Pi bond
b. Ionic bond
c. Sigma bond
d. Covalent bond

12. What electron subshell is generally drawn as three mutually perpendicular double lobe?

a. s
b. p
c. d
d. f

13. The electronic configuration of an element describes how the electrons of its atoms are in the shells, subshells, and orbitals. The term usually applies the atoms in their ground

state. Based on existing principles, what is the ground- state electronic configuration of an atom having 12 electrons?

a. $1s^2\ 2s^2\ 2p^6$
b. $1s^2\ 2s^2\ 2p^6\ 3s^2$
c. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3s^1$
d. $1s^2\ 2s^2\ 2p\ 3s^2\ 3p^6$

14. Considering energy levels, what would be the most probable electron configuration of an atom with an atomic number of 28?

a. 2, 8, 18
b. 2, 8, 8, 2
c. 2, 8, 10, 8
d. 2, 8, 18, 2

15. Which of the following quantitatively describes the removal of electrons from an atom?

a. Bond energy
b. Electron affinity
c. Electronegativity
d. Ionization potential

16. Which of the following has a correct electron dot representation?

a. Mg •

•
• Si •

b. ••
•N•
••

He:

17. Which of the following compound obeys the octet rule?

a. CO_2
b. BCl_5
c. PCl_5
d. SiF_6

18. Which of the following describes a covalent bond?

a. Involves shared electrons
b. Is also called electrovalent
c. Is found by sharing of protons
d. Results from the transfer of electrons

19. Elements in Group IA or IIA normally form ionic bonds between with what groups of elements?

a. Group VIA or VIIA
b. Group VIIA or VIIIA
c. Group VIA or VIIIA
d. Group VA or VIIIA

20. What do you call the measure of the relative tendency of an atom to attract electrons to itself when chemically combined with another atom?

a. Bond energy
b. Electron affinity
c. Electronegativity
d. Ionization potential

21. What constitutes a triple bond?

a. Three pi bond
b. Two sigma and one pi bond
c. one sigma and two pi bond
d. three sigma and no pi bond

22. Which of the following is the simplest alkane?

a. Ethane
b. Methane
c. Methene
d. Ethene

23. What is the name of the compound, As_2S_5?

a. Arsenic disulfide
b. Diarsenic sulfide
c. Arsenic pentasulfide
d. Diarsenic pentasulfide

24. What is the chemical formula of chlorous acid?

a. HClO b. $HClO_4$ c. $HClO_3$ d. $HClO_2$

25. What are the respective coefficients in order to balance the following equation?

$$K_3PO_4 + Ca(NO_3)_2 \longrightarrow KNO_3 + Ca_3(PO_4)_2$$

a. 3, 2, 1, 6 b. 6, 3, 2, 1 c. 6, 2, 1, 3 d. 2, 3, 6, 1

26. When acetylene, C_2H_2 burns in air, the products are CO_2 and H_2O. What is the balanced chemical equation of the reaction?

a. $4\ C_2H_2 + 3\ O_2 \longrightarrow 2\ CO_2 + 3\ H_2O$

b. $3\ C_2H_2 + 4\ O_2 \longrightarrow 3\ CO_2 + 3\ H_2O$

c. $2\ C_2H_2 + 2\ O_2 \longrightarrow 3\ CO_2 + 4\ H_2O$

d. $2\ C_2H_2 + 5\ O_2 \longrightarrow 4\ CO_2 + 2\ H_2O$

27. What are the products formed in the reaction between sulfuric acid and sodium hydroxide?

a. Sodium sulfate + 4 water
b. Sodium sulfate + 3 water
c. sodium sulfate + 2 water
d. sodium sulfate + 1 water

28. Which particular gas is produced in the decomposition of Na_2CO_3?

a. Oxygen
b. Chlorine
c. hydrogen
d. carbon dioxide

29. What is the balanced equation to represent the combination of carbon dioxide and water?

a. $CO_2 + H_2O \longrightarrow H_2CO_3$

b. $CO_2 + H_2O \longrightarrow HCO_3$

c. $CO_2 + 2\ H_2O \longrightarrow H_2CO_3$

d. $2\ CO_2 + 2\ H_2O \longrightarrow 2\ H_2CO_3$

30. What quantity contains as many elementary entities of particles as there are in exactly 12 grams of carbon-12 isotope?

a. Mole
b. Atoms
c. molecules
d. Avogadro's constant

31. What do you call the sum of the atomic masses (in amu) of all the atoms in a molecule?

a. Ionic mass
b. Formula mass
c. empirical mass
d. molecular mass

32. What is the empirical formula of a compound that has a molecular formula of $(NH_4)_{10}P_5W_{30}O_{110}$?

a. $(NH_4)_2PW_6O_{21}$
b. $(NH_4)_2PW_6O_{20}$
c. $(NH_4)_2PW_6O_{22}$
d. $(NH_4)_2PW_5O_{22}$

33. What is the molecular formula of the colorless liquid used in rocket engines, whose empirical formula is NO_2 and has molecular mass of 92 grams? (N=14, O=16)

a. N_2O_3 b. N_2O c. NO_4 d. N_2O_4

34. An oxide of nitrogen contain 30.45 mass % N and 69.55% O. What is the empirical formula of the oxide?

a. NO b. NO_2 c. N_2O d. NO_3

35. What is the result if the temperature of gases rise?

a. The volume will be reduced
b. Diffusion will be slowed down
c. the pressure will go down
d. the particles will move faster

36. Which of the following gas laws states that "the relation between the volume of a gas at constant temperature, and the pressure exerted on it"?

a. Avogadro's Law
b. Gay-Lussac's Law
c. Boyle's Law
d. Charles's Law

37. Which of the following gas laws states that "at the same temperature and pressure, equal volume of gases contain the same number of molecules"?

a. Avogadro's Law
b. Gay-Lussac's Law
c. Boyle's Law
d. Charles's Law

38. What is the process of spreading out spontaneously to occupy a space uniformly with molecules?

a. Diffusion
b. Pressure
c. Avogadro's Law
d. Compressibility

39. What gas law states that “total pressure of a mixture of gases is just the sum of the pressures that each gas would exert if it were present alone”?

a. Dalton’s Law
b. Graham’s Law
c. Avogadro’s Law
d. Gay-Lussac’s Law

40. Boyle’s and Charles’s Laws are readily explained in terms of what theory?

a. Quantum Theory
b. Kinetic Molecular Theory
c. De Broglie Wave Theory
d. Theory of Generalized Relativity

41. A tire that is heated excessively may blow up. What gas law is this a practical application of?

a. Boyle’s Law
b. Charles’s Law
c. Combined Gas Law
d. Gay-Lussac’s Law

42. Why do Mountain Climbers who have reached considerable heights complain of “thin air” and difficulty in breathing?

a. Because the atmospheric pressure is variable
b. Because the atmospheric pressure is lower than at sea level
c. Because the atmospheric pressure is Higher than at sea level
d. Because the atmospheric pressure is Equal to that at sea level

43. Which of the following is described by the concentration of a solution?

a. Nature of solute in relation to its solvent
b. Volume of relationship of solute and solvent
c. Amount of solute dissolved in a given solvent
d. Substances have different intermolecular forces holding their molecules

44. What does the statement “like dissolves like” In solubility means?

a. Substances have similar polar charges
b. Substances form a heterogeneous mixture
c. One is a polar and the other is a nonpolar substance
d. Substances have different intermolecular forces holding their molecules

45. What is the result of dissolving a solute in a solvent?

a. A decrease of the boiling point
b. An increase in the melting point
c. an elevation of freezing point
d. a lowering of the vapor pressure

46. A molal solution is one that contains one mole of solute per ___________.

a. Liter of solvent
b. Liter of solution
c. 1000 grams of solvent
d. 1000 grams of solution

47. What is the concept that defines an acid as any chemical species can accept a pair of electron, and a base as any chemical species that can donate a pair of electron?

a. Lewis b. Sorensen c. Bronsted d. Arrhenius

48. The hydrogen ion is a base proton, but in water solution it is hydrated and exists in what form?

a. Hydrated ion
b. Complex ion
c. hydroxide ion
d. hydronium ion

49. What Bronsted-Lowry acid can be formed when water accepts a proton?

a. H^+ b. H_3O^+ c. NH_4 d. OH^-

50. What is the conjugate base of H_3O^+?

a. H^+ b. OH^- c. H_2O d. H_2O

Appendix H

ORGANIC CHEMISTRY SPATIAL PERFORMANCE TEST

TASK 1

Covalent Bond is formed by overlapping of atomic orbitals. Show the overlapping of orbitals when two Nitrogen atoms bond together to form the Nitrogen molecule and briefly explain your answer.

The bonds formed in the Nitrogen molecule…

TASK 2

Acetic acid (CH3COOH) is the acid contained in vinegar. Show the correct shape of acetic acid and explain why it has such a shape.

The shape of Acetic acid can be explained using…

TASK 3

2-chlorobutane (C_4H_9Cl) can have two configurations, the R configuration and the S configuration. Draw and label the two configurations and tell the difference between the two configurations.

The difference between the two configurations is…

TASK 4

Enantiomers are chiral molecules that are mirror images of one another. Lactic acid ($CH_3CH(OH)COOH$) contains a secondary alcohol and a carboxylic acid functional groups. Draw the enantiomers of lactic acid and differentiate them from one another.

The difference between the enantiomers is…

TASK 5

When Chloroethane (C_2H_5Cl) is attacked by a nucleophile such as a Bromide ion, Bromoethane (C_2H_5Br) results via SN2 reaction and ejecting the Chloride ion. Show the reaction mechanism and state the steps of the reaction.

The formation of Bromoethane via SN2 reaction…

Appendix I

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Name
Title

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Susan Lapham
Director, Project Talent

Appendix J
TABLE OF SPECIFICATION FOR ACHIEVEMENT TEST IN GENERAL CHEMISTRY

TABLE OF SPECIFICATIONS
Achievement Test in General Chemistry

TOPICS	NO. OF ITEMS	LEVELS OF DOMAIN			% (Items)
		Knowledge	Comprehension	Application	
1. Matter and Measurement	8	2, 3, 5	1, 4, 6-8		16
2. Atomic Theory and Atomic Structure					
3. Basic Concepts of Chemical Bonding	6	9, 12	10, 11, 13, 14		12
4. Nomenclature, Chemical Reactions and Equations	8	15, 18, 20, 21	16, 17, 19, 22		16
5. Stoichiometry					
6. Gases	8	23, 24, 28	27	25, 26, 29, 30	16
7. Solutions					
8. Acids and Bases					
Total	4	31		32, 33, 34	8
	8	36-39	35, 40	41, 42	16
	4	46	43-45		8
	4	49, 50	47, 48		8
	50	20	21	9	100

Appendix K

SCORING GUIDE FOR THE STUDENTS' ANSWERS IN THE ORGANIC CHEMISTRY SPATIAL PERFORMANCE TEST

TASK	STRUCTURE			CONCEPT		
	1	2	3	1	2	3
Covalent Bond is formed by overlapping of atomic orbitals. Show the overlapping of orbitals when two Nitrogen atoms bond together to form the Nitrogen molecule and briefly explain your answer.	Shows the bond between the two nitrogen atoms as lines	Showed the 3D head to head overlapping of the sigma bond and 2D lateral overlapping of the pi bonds. Designation of axis and lone pairs are not clearly defined.	Clearly showed the 3D head to head overlapping of the sigma bond and lateral overlapping of the pi bonds. Designation of axis and lone pairs are clearly defined.	States that three bonds are formed	States that three bonds are formed, one sigma bond and two pi bonds	States that three bonds are formed, one sigma bond and two pi bonds, sigma bond being head to head overlapping and pi bond as lateral overlapping. **Optional:** Lone pairs are in sp configuration
Acetic acid (CH_3COOH) is the acid contained in vinegar. Show the correct shape of acetic acid and explain why it has such a shape.	Shows the correct number of atoms of each element with 2D	Shows the correct number of atoms of each element with 3D bonds	Shows the correct number of atoms of each element with 3D bonds with broken lines and wedges to indicate position	States the correct molecular geometry of Acetic acid ——— – only one VSEPR shape is	States the correct molecular geometry of Acetic acid and explains the complete shape using VSEPR ________	States the correct molecular geometry of Acetic acid and explains the complete shape using VSEPR and Hybridization

	bonds			mentioned.	Only one hybridized orbital mentioned.	
2-chlorobutane (C_4H_9Cl) can have two configurations, the R configuration and the S configuration. Draw and label the two configurations and tell the difference between the two configurations.	Shows the 2D representation of both configurations	Shows the 3D representation of both configurations with correct labels	Shows the 3D representation of both configurations with broken lines and wedges to show position With proper labels	States that the molecules are rotated clockwise and counterclockwise	States that the substituent priorities rotates in the clockwise and counterclockwise direction.	States that the substituent priorities rotates in the clockwise and counterclockwise direction, properly citing the Rectus (R) and Sinister (S) configuration of 2-chlorobutane.

Enantiomers are chiral molecules that are mirror images of one another. Lactic acid ($CH_3CH(OH)COOH$) contains a secondary alcohol and a carboxylic acid functional groups. Draw the enantiomers of lactic acid and differentiate them from one another.	Draws a 2D representation of both enantiomers	Shows the 3D representation of both enantiomers	Shows the 3D representation of both enantiomers with broken lines and wedges to show position	States that the two molecules are mirror images of one another	States that the two molecules are mirror images of one another and are non-superimposable	States that the two molecules are chiral molecules that are mirror images of one another and are non-superimposable and is flipped by 180 degrees
When Chloroethane (C_2H_5Cl) is attacked by a nucleophile such as a Bromide ion, Bromoethane (C_2H_5Br) results via S_N2 reaction and ejecting the Chloride ion. Show the reaction mechanism and state the steps of the reaction.	Shows the reactant and product with 2D bonds	Shows a complete reaction mechanism with 2D/3D bonds	Shows a complete reaction mechanism with 3D bonds with broken lines and wedges to indicate position	States that the reaction is a substitution reaction	States that the reaction is a substitution reaction without the formation of an intermediate	States that the reaction is a substitution reaction without the formation of an intermediate and the final product has an inverted stereochemistry.

Appendix L

VALIDATION RESULT – ACHIEVEMENT TEST

Criteria	Evaluator 1	Evaluator 2	Evaluator 3
A. CONTENT			
a. Topics being measured are in the scope of the curriculum.	3	4	4
b. Items are relevant to the topic/subject being measured.	3	4	4
c. There is only one correct answer per question.	3	4	4
B. ITEMS			
a. Number of items per topic is sufficiently distributed.	3	4	4
b. Number of items is correctly assigned in the Table of Specifications.	3	4	4
c. Number of items is sufficient to measure achievement of students in the subject being measured.	3	4	4
C. LEVEL OF DIFFICULTY			
a. There are no hints in each question.	3	4	4
b. Level of difficulty is parallel to the students' academic level.	3	4	4
c. The instrument indicates the level of performance which increases with equal increment that is parallel to the students' skill level.	3	4	4
D. STRUCTURE			

a. The instrument has a clear heading such as the date, name, and title.	3	4	3
b. The instrument has a clear layout such as margins, spaces in between questions and choices.	3	4	3
c. Font size, style, letters/numbers and spacing are uniform throughout the instrument.	3	4	3
E. INSTRUCTIONS			
a. Instructions are well constructed.	3	4	4
b. Instructions are clear and easy to follow.	3	4	4
c. Instructions are appropriate for the type of test.	3	4	4
F. LANGUAGE			
a. The instrument is free of any errors in punctuation.	3	4	4
b. The instrument contains correct capitalization of words.	3	4	4
c. The instrument is free from grammatical errors.	3	4	4
G. ETHICAL/SOCIAL			
a. The instrument contains relevant or associated texts that are free from offensive language.	3	3	4
b. The instrument is free from cultural discrimination.	3	3	4
c. The instrument has equal reference to both male and female gender in the test questions.	3	3	4

Appendix M

VALIDATION RESULT – OCSPT

Criteria	Evaluator 1	Evaluator 2	Evaluator 3
A. The OBJECTIVES of the test:			
1. Are measurable and attainable.	3	3	3
2. Cover the expected contents.	2	4	3
3. Are relevant to the competencies on Organic Chemistry.	2	4	4
B. The CONTENT of the test:			
A. CONCEPT			
1. Are within the topics covered by the subject being measured.	3	4	3
2. Can help elicit and address the common misconception.	2	2	4
3. Can measure the level of understanding of students in the subject being measured.	2	2	4
B. SPATIAL			
1. Is relevant to the subject being measured.	3	4	4
2. Contain topics that require mental visualization.	3	4	4
3. Can measure the student's level of spatial orientation.	2	3	4
C. The STRUCTURE of the test:			
1. Has a clear and definite format.	2	4	3
2. Has an appealing and readable layout.	3	4	4
3. Includes clear and brief instructions.	2	3	3

D. The LANGUAGE of the test:			
1. Is free from grammatical errors.	3	4	4
2. Is easy to comprehend.	3	4	3
3. Has a reasonable amount of technical terms.	3	4	3
E. The test is USEFUL in terms of:			
1. Using as an assessment tool.	2	4	4
2. Diagnosing student's misconceptions.	3	3	4
3. Using as collaborative class activity.	3	4	4
II. ORGANIC CHEMISTRY SPATIAL PERFORMANCE TEST RUBRICS			
The SCORING RUBRICS:			
1. Has a scoring guide which is clear and easy to understand.	1	4	3
2. Is easy follow and assign a score.	1	4	4
3. Measures the degree of conceptual and spatial understanding of the students.	1	3	4
4. Contains proper descriptions in each item and sample student response.	1	3	3
5. Provides specific boundaries between scores to avoid scoring confusion.	3	4	3

Appendix N

FREQUENCY TABLES

Category	Frequency table: MCXX (TENGCO)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	2	2	4.65116	4.6512
2	35	37	81.39535	86.0465
3	6	43	13.95349	100.000
Missing	0	43	0.00000	100.000

Category	Frequency table: ABSX (TENGCO)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	10	10	23.25581	23.2558
2	33	43	76.74419	100.000
Missing	0	43	0.00000	100.000

Category	Frequency table: MECHX (TENGCO)			
	Count	Cumulative Count	Percent	Cumulative Percent
0	7	7	16.27907	16.2791
1	32	39	74.41860	90.6977
2	4	43	9.30233	100.000
Missing	0	43	0.00000	100.000

Category	Frequency table: 2DX (TENGCO)			
	Count	Cumulative Count	Percent	Cumulative Percent
0	13	13	30.23256	30.2326
1	6	19	13.95349	44.1860
2	24	43	55.81395	100.000
Missing	0	43	0.00000	100.000

Category	Frequency table: 3DX (TENGCO)			
	Count	Cumulative Count	Percent	Cumulative Percent
0	4	4	9.30233	9.3023
1	28	32	65.11628	74.4186
2	11	43	25.58140	100.000
Missing	0	43	0.00000	100.000

Category	Frequency table: COMPX (TENGCO)			
	Count	Cumulative Count	Percent	Cumulative Percent
1	34	34	79.06977	79.0698
2	9	43	20.93023	100.000
Missing	0	43	0.00000	100.000

Category	Frequency table: OEXX (TENGCO)			
	Count	Cumulative Count	Percent	Cumulative Percent
0	22	22	51.16279	51.1628
1	19	41	44.18605	95.3488
2	2	43	4.65116	100.000
Missing	0	43	0.00000	100.000

Appendix O

BREAKDOWN TABLE OF DESCRIPTIVE STATISTICS

Breakdown Table of Descriptive Statistics (TENGCO)
N=43 (No missing data in dep. var. list)

MCXX	MC Means	MC N	MC Std.Dev.	MC Minimum	MC Maximum
1	24.5000	2	0.70710	24.0000	25.0000
2	32.5142	35	3.36392	26.0000	38.0000
3	42.3333	6	2.06559	40.0000	45.0000
All Grps	33.5116	43	5.04914	24.0000	45.0000

Breakdown Table of Descriptive Statistics (TENGCO)
N=43 (No missing data in dep. var. list)

ABSX	ABS Means	ABS N	ABS Std.Dev.	ABS Minimum	ABS Maximum
1	8.8000	10	1.31656	7.0000	10.0000
2	12.3939	33	1.08798	11.0000	15.0000
All Grps	11.5581	43	1.90616	7.0000	15.0000

Breakdown Table of Descriptive Statistics (TENGCO)
N=43 (No missing data in dep. var. list)

MECHX	MECH Means	MECH N	MECH Std.Dev.	MECH Minimum	MECH Maximum
0	4.71428	7	0.95119	3.00000	6.0000
1	9.37500	32	1.49730	7.00000	13.0000
2	16.2500	4	1.70782	14.0000	18.0000
All Grps	9.2558	43	3.17799	3.00000	18.0000

Breakdown Table of Descriptive Statistics (TENGCO)
N=43 (No missing data in dep. var. list)

2DX	2D Means	2D N	2D Std.Dev.	2D Minimum	2D Maximum
0	4.5384	13	2.18385	2.0000	8.0000
1	11.5000	6	2.73861	9.0000	16.0000
2	21.5000	24	1.61514	19.0000	24.0000
All Grps	14.9767	43	7.96566	2.0000	24.0000

Breakdown Table of Descriptive Statistics (TENGCO)
N=43 (No missing data in dep. var. list)

3DX	3D Means	3D N	3D Std.Dev.	3D Minimum	3D Maximum
0	4.7500	4	0.50000	4.0000	5.0000
1	8.6428	28	1.66030	6.0000	11.0000
2	12.6363	11	0.67420	12.0000	14.0000
All Grps	9.3023	43	2.65952	4.0000	14.0000

Breakdown Table of Descriptive Statistics (TENGCO)
N=43 (No missing data in dep. var. list)

COMPX	COMP Means	COMP N	COMP Std.Dev.	COMP Minimum	COMP Maximum
1	73.676	34	12.8905	44.5000	88.500
2	103.333	9	8.6674	96.0000	119.000
All Grps	79.883	43	17.1432	44.5000	119.000

Breakdown Table of Descriptive Statistics (TENGCO)
N=43 (No missing data in dep. var. list)

OEXX	OE Means	OE N	OE Std.Dev.	OE Minimum	OE Maximum
0	3.2727	22	1.77768	1.0000	6.0000
1	9.0526	19	1.470967	7.0000	12.0000
2	16.00000	2	1.414214	15.0000	17.0000
All Grps	6.4186	43	3.905018	1.0000	17.0000

Breakdown Table of Descriptive Statistics (TENGCO) N=43 (No missing data in dep. var. list)					
OEXX	MC Means	MC N	MC Std.Dev.	MC Minimum	MC Maximum
0	31.8181	22	4.85637	24.0000	44.0000
1	34.5263	19	4.20804	26.0000	43.0000
2	42.5000	2	3.53553	40.0000	45.0000
All Grps	33.5116	43	5.04914	24.0000	45.0000

Breakdown Table of Descriptive Statistics (TENGCO) N=43 (No missing data in dep. var. list)					
ABSX	MC Means	MC N	MC Std.Dev.	MC Minimum	MC Maximum
1	32.3000	10	4.11096	27.0000	40.0000
2	33.8787	33	5.30187	24.0000	45.0000
All Grps	33.5116	43	5.04914	24.0000	45.0000

Breakdown Table of Descriptive Statistics (TENGCO) N=43 (No missing data in dep. var. list)					
MECHX	MC Means	MC N	MC Std.Dev.	MC Minimum	MC Maximum
0	30.5714	7	3.30943	26.0000	34.0000
1	33.8437	32	5.08704	24.0000	44.0000
2	36.0000	4	6.16441	32.0000	45.0000
All Grps	33.5116	43	5.04914	24.0000	45.0000

Breakdown Table of Descriptive Statistics (TENGCO) N=43 (No missing data in dep. var. list)					
2DX	MC Means	MC N	MC Std.Dev.	MC Minimum	MC Maximum
0	31.4615	13	4.92638	24.0000	40.0000
1	32.8333	6	4.44597	26.0000	38.0000
2	34.7916	24	5.03879	25.0000	45.0000
All Grps	33.5116	43	5.04914	24.0000	45.0000

Breakdown Table of Descriptive Statistics (TENGCO) N=43 (No missing data in dep. var. list)					
3DX	MC Means	MC N	MC Std.Dev.	MC Minimum	MC Maximum
0	35.0000	4	4.96655	29.0000	40.0000
1	32.3928	28	4.96908	24.0000	44.0000
2	35.8181	11	4.77112	29.0000	45.0000
All Grps	33.5116	43	5.04914	24.0000	45.0000

Breakdown Table of Descriptive Statistics (TENGCO) N=43 (No missing data in dep. var. list)					
COMPX	MC Means	MC N	MC Std.Dev.	MC Minimum	MC Maximum
1	32.5294	34	4.66603	24.0000	44.0000
2	37.2222	9	4.94413	32.0000	45.0000
All Grps	33.5116	43	5.04914	24.0000	45.0000

Appendix P

ANALYSIS OF VARIANCE

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
	Analysis of Variance (TENGCO) Marked effects are significant at p < .05000							
MC	244.234	2	122.117	826.509	40	20.6627	5.91002	0.00564

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
	Analysis of Variance (TENGCO) Marked effects are significant at p < .05000							
MC	19.1290	1	19.1290	1051.61	41	25.6491	0.74579	0.39283

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
	Analysis of Variance (TENGCO) Marked effects are significant at p < .05000							
MC	88.8111	2	44.4055	981.933	40	24.5483	1.80890	0.17698

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
	Analysis of Variance (TENGCO) Marked effects are significant at p < .05000							
MC	96.7217	2	48.3608	974.022	40	24.3505	1.98602	0.15054

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
	Analysis of Variance (TENGCO) Marked effects are significant at p < .05000							
MC	102.429	2	51.2146	968.314	40	24.2078	2.11561	0.13385

Variable	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
	Analysis of Variance (TENGCO) Marked effects are significant at p < .05000							
MC	156.718	1	156.718	914.026	41	22.2933	7.02982	0.01134

Appendix Q

CORRELATIONS

Variable	Correlations (TENGCO) Marked correlations are significant at $p < .05000$ N=43 (Casewise deletion of missing data)						
	MC	ABS	MECH	2D	3D	COMP	OE
MC							
ABS	0.286276						
MECH	0.346280	0.309954					
2D	0.314059	0.193750	0.309677				
3D	0.176153	0.341653	0.480796	0.201510			
COMP	0.387861	0.557603	0.714654	0.687633	0.768713		
OE	0.522622	0.178970	0.415166	0.403703	0.267213	0.467192	

Effect	Analysis of Variance; DV: MC (TENGCO)				
	Sums of Squares	df	Mean Squares	F	p-level
Regress.	353.402	5	70.68037	3.645643	0.008811
Residual	717.342	37	19.38763		
Total	1070.744				

N=43	Regression Summary for Dependent Variable: MC (TENGCO) R= .57450200 R²= .33005255 Adjusted R²= .23951911 F(5,37)=3.6456 p<.00881 Std.Error of estimate: 4.4031					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(37)	p-level
Intercept			23.14891	4.321301	5.356929	0.000005
ABS	0.181408	0.146155	0.48052	0.387145	1.241199	0.222344
MECH	0.124097	0.166414	0.19715	0.264395	0.745678	0.460573
2D	0.084250	0.149960	0.05340	0.095053	0.561791	0.577640
3D	-0.076016	0.158183	-0.14432	0.300310	-0.480562	0.633657
OE	0.424937	0.156380	0.54944	0.202200	2.717224	0.009955

N=43	Regression Summary for Dependent Variable: MC (TENGCO) R= .52262155 R²= .27313329 Adjusted R²= .25540483 F(1,41)=15.406 p<.00032 Std.Error of estimate: 4.3569					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(41)	p-level
Intercept			29.17425	1.289393	22.62639	0.000000
OE	0.522622	0.133148	0.67574	0.172155	3.92511	0.000324

CURRICULUM VITAE

PERSONAL DETAILS

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EDUCATIONAL ATTAINMENT

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Tertiary	Philippine Normal University Bachelor of Science in Chemistry for Teachers 2006-2010
Secondary	Philippine Normal University Center for Teaching and Learning 1998-2002

AWARDS AND DISTINCTIONS

7th Placer, Licensure Examination for Teachers (LET)
Sept. 2010

Cum Laude
Rank #5, Batch 2010

Scholar, PLDT Gabay-Guro Scholarship
2007-2010

VP for Academics
Chemical Society
2008-2009

Rank # 1 Student with Highest Combined GPA (Class Level)
2nd Semester SY 2007-2008 and 1st Semester

WORK EXPERIENCES

Technological University of the Philippines
Instructor (Part-time)
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Philippine Normal University
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Science Teacher, SY 2010-2011

RESEARCHES

Undergraduate Development of a Multimeter Add-on for Chemistry Applications
UNDERGRADUATE RESEARCH

Graduate Relationship between Spatial Intelligence and Performance of Chemistry Majors at Philippine Normal University
MASTER'S THESIS

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Licensure Examination for Teachers
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C E R T I F I C A T I O N

This is to certify that the thesis of **LARRY F. TENCO** titled "**LEVEL OF SPATIAL INTELLIGENCE AND PERFORMANCE OF CHEMISTRY MAJORS AT PHILIPPINE NORMAL UNIVERSITY**" was language-edited in May 2014 by the undersigned language editor.

RAMER V. OXIÑO, MAT ELA
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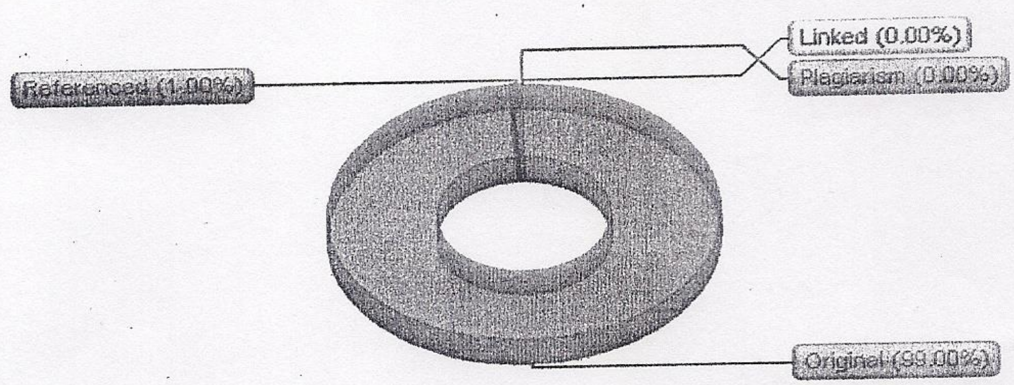

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